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May 25, 2023
Report 2022-106
FACT SHEET

Grant Parks *California State Auditor*

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Department of Water Resources

Its Forecasts Do Not Adequately Account for Climate Change and Its Reasons for Some Reservoir Releases Are Unclear

Background

The Department of Water Resources (DWR) and State Water Resources Control Board (State Water Board) have key responsibilities in managing California's surface water. State law requires DWR to develop annual forecasts of the State's water supply, which affect water management at both the state and local level. DWR also manages the State Water Project, a water storage and delivery system that supplies water to almost 27 million Californians and 750,000 acres of farmland. The State Water Board administers water rights and controls water quality. The increasing effects of climate change have had ramifications for the State's water supply, and climate researchers project that these effects will continue to increase, including by causing more frequent and severe drought. DWR has pledged to play a leadership role in adapting to the effects of climate change.

Key Recommendations

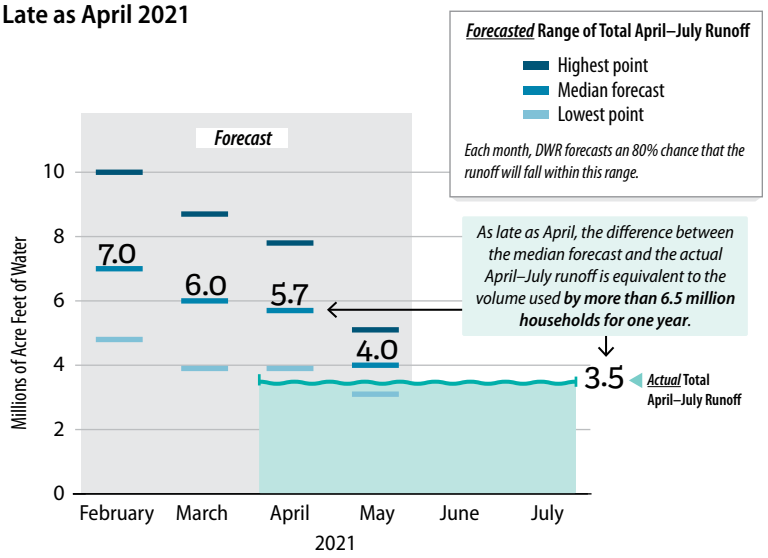
DWR should do the following to ensure its effective management of surface water:

- Implement a formal process for annually evaluating the accuracy of its forecasts and implementing plans to improve them.
- Continue implementing its plan to adopt a new water supply forecasting model and procedures that better address the effects of climate change and provide updates on its website.
- Develop a comprehensive, long-term plan for mitigating and responding to the effects of drought, including more frequent and more severe droughts, on the State Water Project.
- Implement a formal policy and procedures for documenting its operational plans and the rationale for its operational decisions, including regarding reservoir releases.

Key Findings

- In water year 2021, DWR significantly overestimated the water supply. The figure depicts DWR's error for the Sacramento Valley and San Joaquin Valley regions. DWR attributed its error to severe conditions brought on by climate change. The State Water Board does not participate in DWR's development of water supply forecasts.

DWR Significantly Overestimated the State's 2021 Water Supply as Late as April 2021



- DWR has not fully adapted its forecasting model and procedures to account for the effects of climate change, despite acknowledging the need to do so more than a decade ago. Some federal and local agencies use models that take into account data that is relevant to climate change, such as temperature and soil moisture.
- DWR has not developed a comprehensive, long-term plan for mitigating or responding to the effects of more severe future droughts on the State Water Project.
- DWR balances multiple demands on water from the State Water Project, including meeting the needs of water users, protecting wildlife, and storing water for future use. However, DWR did not adequately document its rationale for significant releases in water years 2021 and 2022.
- DWR lacks formal processes for reviewing and improving the effectiveness of both its water supply forecasts and its reservoir operations.

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Grant Parks *State Auditor*

May 25, 2023
2022-106

The Governor of California
President pro Tempore of the Senate
Speaker of the Assembly
State Capitol
Sacramento, California 95814

Dear Governor and Legislative Leaders:

As directed by the Joint Legislative Audit Committee, my office conducted an audit of the Department of Water Resources (DWR) and the State Water Resources Control Board. Our assessment focused on DWR's water supply forecasting and surface water management, and we determined that DWR has made only limited progress in accounting for the effects of climate change in its forecasts of the water supply and in its planning for the operation of the State Water Project. Until it makes more progress, DWR will be less prepared than it could be to effectively manage the State's water resources in the face of more extreme climate conditions.

DWR is responsible for developing water supply forecasts that are important to both state and local efforts in managing California's finite water resources. Despite acknowledging more than a decade ago that it needed to adopt a new forecasting method that better accounts for the effects of climate change, DWR has continued to rely heavily on historical climate data when developing its forecasts. In fact, in water year 2021, DWR significantly overestimated the State's water supply—an error that DWR attributed to severe conditions due to climate change. DWR has since begun planning to adapt its forecasting model and associated procedures, but it could better ensure that it is using the best approach available if it adopted a formal process for evaluating the quality of its forecasts.

Large numbers of California's residents and much of its agriculture depend on DWR's effective management of the State Water Project. Although researchers project that climate change will significantly challenge the project's operations, DWR has not developed a comprehensive, long-term plan for the State Water Project that meets best practices for proactively mitigating or responding to drought—particularly more frequent or more severe future droughts. Further, DWR has not maintained sufficient documentation to demonstrate that some releases it made from the Lake Oroville reservoir in water years 2021 and 2022 were appropriate in volume. DWR's limited documentation in this key operating area impairs its capacity to demonstrate adequate stewardship of the State Water Project. Insufficient documentation also hinders DWR's ability to effectively evaluate and, to the extent necessary, improve its management of the State Water Project to ensure the most efficient use of the State's limited water supply.

Respectfully submitted,

GRANT PARKS
California State Auditor

Selected Abbreviations Used in This Report

CNRFC	California Nevada River Forecast Center
DWR	Department of Water Resources
FEMA	Federal Emergency Management Agency
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NDMC	National Drought Mitigation Center
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service

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Summary

Climate change has had significant ramifications for the State's water supply, and researchers project that its effects will increase in the future. Nonetheless, the Department of Water Resources (DWR) has been slow to account for the effects of climate change on key responsibilities related to managing the State's water resources.

For example, one of DWR's responsibilities is to develop water supply forecasts on which both state and local water agencies rely. However, DWR has not adequately ensured that its forecasts account for the effects of climate change. Similarly, it has not developed a comprehensive, long-term plan for managing the State Water Project—a water storage and delivery system that collects surface water from the northern part of the State and delivers it to both the Bay Area and Southern California—during periods of more severe future drought. Addressing these issues will better prepare DWR to more effectively manage the State's water resources in the face of increasingly extreme conditions.

DWR Has Not Adequately Ensured That Its Water Supply Forecasts Account for the Effects of Climate Change

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In water year 2021, DWR significantly overestimated the State's water supply. For example, in its February median forecasts, DWR projected that runoff would be at least twice the volume that actually occurred in the majority of watersheds for which it produces forecasts. Significant errors in DWR's forecasts can affect state and local efforts to effectively manage the water supply, in part because of operational requirements tied to the forecasts. DWR attributed its error to the extreme conditions brought on by climate change. However, DWR has continued to rely heavily on historical climate data when developing its forecasts, despite its own acknowledgment more than a decade ago that its forecasting methods needed to better account for the effects of climate change. DWR's limited progress in adopting a new forecasting model and related procedures stands in contrast to the efforts of other agencies we reviewed. Although those agencies' specific forecasting models differ, each directly incorporates observed or modeled data that is relevant to climate change, such as temperature and soil moisture. Following the significant error in its water year 2021 forecasts, DWR developed a plan to make its forecasting more resilient to the effects of climate change, and DWR has entered into various contracts for technical assistance to improve its forecasts. However, if DWR also adopted a formal process for evaluating the quality of its own forecasts, it would be better positioned to ensure that it is using the best forecasting approach available.

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DWR Must Do More to Prepare for the Impact of More Severe Droughts on the State Water Project's Operations

DWR has not developed a long-term plan for the State Water Project that aligns with best practices for proactively mitigating or responding to drought. In particular, although DWR has published strategies for responding to immediate conditions after droughts have begun, it has not developed comprehensive plans to respond to the effects that more severe future droughts may have on State Water Project operations. Such a plan could, for example, take into account the project's ability to meet water quality and flow standards for the protection of wildlife in the face of more extreme conditions. In addition, DWR has not maintained sufficient documentation explaining how it decided that significant releases it made from its Lake Oroville reservoir in water years 2021 and 2022 were appropriate in scale. Improved recordkeeping would better position DWR to explain its decision making to water stakeholders and the general public as well as allow it to more consistently and reliably evaluate its release decisions and improve its future operations.

Agency Response

DWR generally disagrees with our report findings and recommendations. Specifically, DWR does not believe it has been slow to account for climate change in its forecasts, does not believe it lacks a comprehensive, long-term plan for responding to droughts, and does not believe it lacks sufficient records demonstrating the need for certain water releases from the State Water Project. Further, it believes many of our audit's recommendations will add an additional layer of processes and procedures that it equates to "paperwork."

Recommendations

The following are the recommendations we made as a result of our audit. Descriptions of the findings and conclusions that led to these recommendations can be found in the sections of this report.

DWR

To ensure that its B120 water supply forecasts are as accurate as possible, DWR should implement a forecast verification process by November 2023 that includes the following:

- An annual evaluation of the accuracy of each of its monthly forecasts using multiple means in accordance with best practices, including an assessment of whether actual runoff fell within its probability range and an assessment of the accuracy of its median forecast.
- Identification of the likely causes of greater-than-expected forecast errors.
- An annual assessment of opportunities for improvement and enhancement, including identifying and evaluating available and emerging forecasting technologies.
- The development and implementation of plans to improve its forecasts based on the findings from its annual evaluation.
- Annual reporting on its water supply forecasting web page about the above actions so that the public is aware of the steps it is taking to improve and enhance the accuracy and predictive capability of its forecasts.

To ensure that its water supply forecasts better account for the observed effects of climate change as soon as possible, DWR should continue to implement its plan to adopt an updated water supply forecasting model and updated procedures. By November 2023 DWR should also do the following:

- Publish on its website a timeline affirming when it will implement its updated model and procedures across all of the watersheds for which it produces a water supply forecast.
- Establish and publish the specific criteria that it will employ to determine when its updated model has demonstrated sufficient predictive capability to be ready for use in each of the watersheds.
- Provide annual updates on its website regarding the status of its implementation of the updated model and procedures.

To better prepare to effectively manage State Water Project operations during future, possibly more extreme drought periods, DWR should, by May 2024, develop a long-term plan for proactively mitigating and responding to the impacts of drought on the project. In accordance with drought preparation best practices, DWR should include the following components in the plan:

- An assessment of the potential impacts of drought on the State Water Project that accounts for the possibility that climate change may result in more severe droughts.
- An assessment of DWR's current capability to address those potential impacts, as well as the identification of any steps that DWR must take to gain needed capabilities.
- Specific strategies for operating the State Water Project to mitigate and respond to the identified impacts of drought while still achieving the project's objectives.
- A description of the circumstances that would trigger DWR to begin implementing its drought response strategies.
- Provisions requiring DWR to update the drought plan at least once every five years and also after each drought to incorporate lessons learned.

To ensure that it can demonstrate effective oversight of State Water Project operations and efficient use of the project's water supply, DWR should, by May 2024, develop and implement a policy and set of procedures for documenting the following:

- Its monthly and annual plans for operating the State Water Project, including the amount of water that it intends to release, store, and export.
- The rationale behind its plans and an explanation of how the plans will help it to achieve the project's objectives.
- A description of any changes that it makes during its operations that deviate from its plans.
- The rationale for any changes that it makes, including the conditions that led to the change, the specific reason for the change, and any viable alternatives that it considered.
- The degree to which it succeeds in achieving each of the project's various objectives on a monthly and annual basis.

To ensure that its operation of the State Water Project reflects the possibility of more extreme climate conditions, DWR should, by May 2024, evaluate the data and information that it relies upon in its monthly and annual planning for its Lake Oroville reservoir operations, including the volumes of water that it will need to store to achieve its objectives. It should update the data and information as needed.

To ensure that it continually improves the effectiveness of its management of the State Water Project, DWR should develop and implement a formal, written process for reviewing its planning and operations at least once annually. This process should include the following:

- An assessment of DWR's success at achieving each of the project's various objectives.

- An evaluation of DWR's actions to achieve its objectives, including the decisions that it made in its planning and in its day-to-day management of the project. DWR should identify actions that assisted it in achieving its objectives and that would benefit its operations in the future, as well as actions that were less effective.

- Documentation of lessons learned from the evaluation of its actions and, if necessary, updates to its planning or procedural documents to incorporate changes.

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Introduction

Background

State law requires the Department of Water Resources (DWR) to develop annual forecasts of the State's seasonal water supply, which DWR does each water year.[1] Surface water—supplied by runoff from rain and snowfall—makes up a significant proportion of the water that California uses for agricultural, residential, municipal, and industrial purposes. During winter storms, snow accumulates in the mountains, generally reaching its highest total amounts in early April. In the spring and summer, the snow melts, running down the mountains and flowing into rivers and streams. Some of this water makes its way into reservoirs. DWR's forecasts of the water supply have important implications for water management for many parts of the State.

DWR's Statewide Water Supply Forecasts

As Figure 1 shows, DWR provides water supply forecasts for various watersheds across the State.[2] From February through May, DWR's Snow Surveys and Water Supply Forecasting unit (forecasting unit) issues a monthly publication called the *Bulletin 120* (B120). The B120 presents DWR's forecasts of the total surface water that it predicts will run off through each watershed from April through July. As we describe in more detail later, DWR generally bases those forecasts on rain, snow, and runoff. As part of doing so, it obtains data on snow through measurements of the snow in the Sierra and Shasta-Trinity mountains, via the California Cooperative Snow Surveys program (Snow Survey). Led by DWR, the Snow Survey is a collaborative effort among local, state, federal, and private entities that involves the periodic measurement of snow levels at predetermined locations.

When publishing its B120 forecast, DWR provides both its *median* forecast and its *80 percent probability range* (probability range). The median forecast represents roughly the midpoint in the probability range. The probability range represents broader parameters for possible runoff with an expected 80 percent chance that the runoff will fall somewhere within it. For example, DWR's March 2021 median forecast of the total inflow to the Lake Shasta reservoir was 1.2 million acre feet of water, and its probability range projected an 80 percent chance that the total inflow would be from 0.97 million to 1.52 million acre feet of water.

According to DWR, the B120 forecast is a key tool for water managers across the State, and it has important legal impacts for water rights holders. The text box includes examples that DWR has identified of water forecasts' uses. Moreover, DWR's B120 forecasts affect requirements for state, federal, and certain local water agencies, such as the volume of water

Examples of How DWR's Water Supply Forecasts Are Used

Agricultural

- Determining crop planting patterns.
- Developing irrigation schedules.
- Evaluating the need to pump ground water.

Municipal

- Evaluating city and county water supplies.
- Informing water conservation decisions.

Public Utilities

- Determining the percentage of energy generation that will be hydro power.

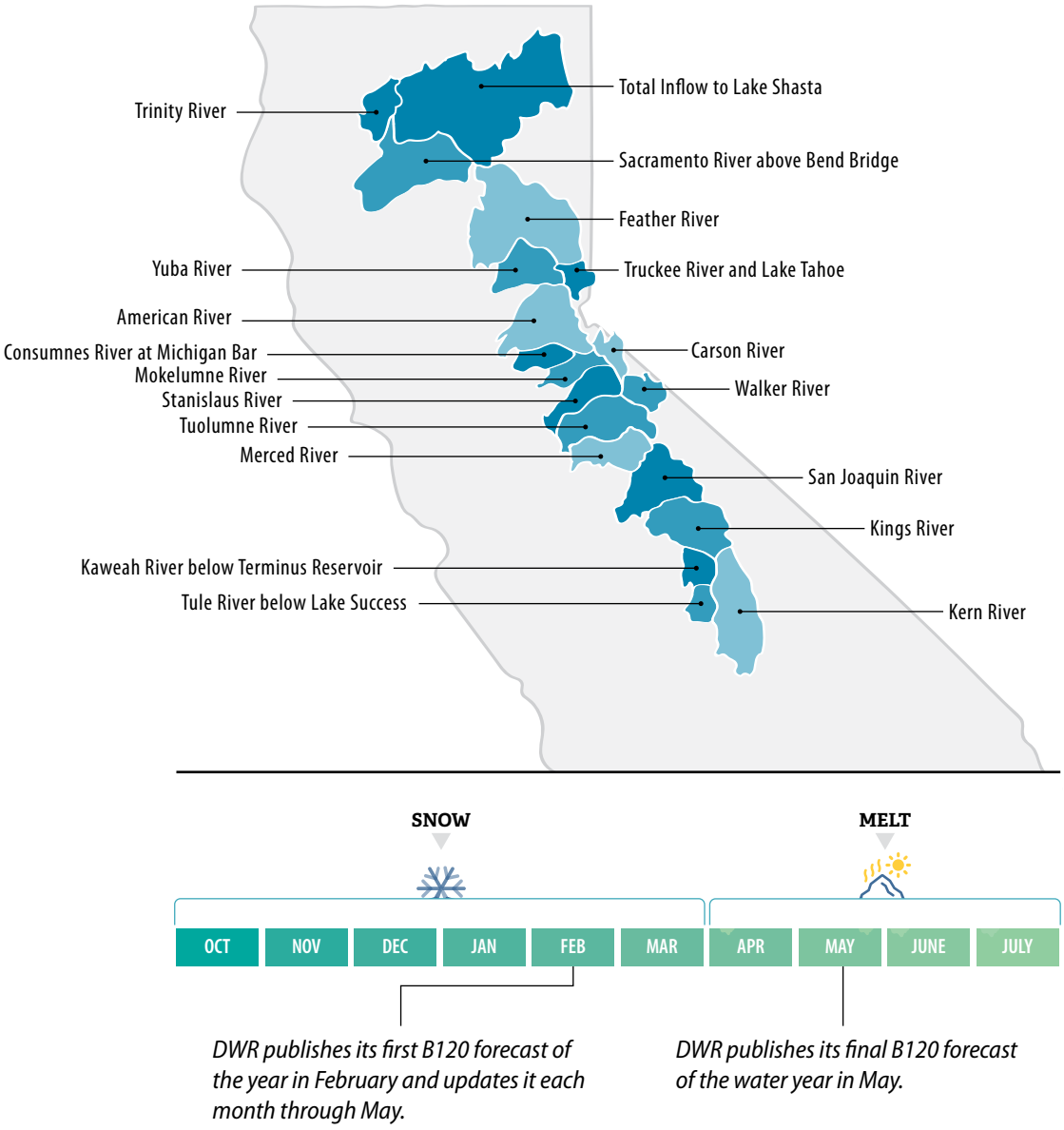
Source: DWR.

[1] A water year runs from October 1 through September 30 and is labeled by the year in which it ends. For example, water year 2022 began on October 1, 2021, and ended on September 30, 2022.

[2] A watershed is the land area from which water drains into a stream, river, or reservoir.

they must release from reservoirs. Some of these requirements are affected specifically by the B120's median forecast. Thus, variances between DWR's forecasts and actual runoff can affect water management in the State.

Figure 1
From February Through May, DWR Publishes B120 Water Supply Forecasts for Watersheds Across the State



Source: DWR water supply forecasting documentation.

DWR's Administration of the State Water Project

In addition to providing forecasts of the State's surface water supply, DWR manages the State Water Project, a multipurpose water storage and delivery system made up of canals, pipelines, and reservoirs. The State Water Project delivers water through contracts DWR has with 29 cities, counties and water districts, known collectively as *State Water Project contractors*. The State Water Project collects surface water from the northern part of the State in the project's largest reservoir, Lake Oroville. From there, water flows through the Feather and Sacramento rivers into the Sacramento-San Joaquin Delta (Delta). The State Water Project captures water from the Delta by exporting it via pumping plants and conveys it through several facilities to State Water Project contractors. In total, the State Water Project supplies water to almost 27 million Californians and 750,000 acres of farmland.

As Figure 2 shows, various legal obligations affect DWR's operation of the State Water Project. For example, DWR holds contracts with various water rights holders that require DWR to provide those water rights holders with specified amounts of water each year, depending in part on the water supply. Moreover, federal law requires DWR to operate the Lake Oroville reservoir, in part, for flood control purposes by reserving a certain amount of storage space in the reservoir for flood control.

In addition, important requirements related to water quality and flow in the Delta also affect DWR's operation of the State Water Project. The Legislature has declared that the Delta is a critically important natural resource for the State and the nation, noting that it serves as both the hub of the California water system and the most valuable estuary and wetland ecosystem on the west coast of North and South America. Moreover, the Delta provides habitat to threatened and endangered species, such as the Delta smelt and the Chinook salmon. Given the Delta's importance, the State Water Project is subject to a number of requirements to ensure proper flow and water quality in the Delta, such as ensuring that the concentration of salt (salinity) remains below thresholds established to protect agriculture and wildlife.

The federal Bureau of Reclamation (Reclamation) operates the related Central Valley Project, which delivers water in 29 counties in the State for agriculture, municipal and industrial use, and wildlife refuges. Reclamation shares responsibility with DWR for meeting Delta water quality and flow requirements, which both agencies may do by making releases from reservoirs and adjusting the amount of water that they pump from the Delta. To meet the water quality and flow requirements, the two agencies must coordinate their efforts.

Figure 2
Multiple Legal Obligations Affect DWR's Operation of the State Water Project

DWR and Reclamation are able to pump some of the water out of the Delta to supply State Water Project and Central Valley Project contractors. The amount they can pump depends, in part, on water quality, Delta outflow requirements, and protected wildlife conditions.

Additional contracts require DWR to provide water to various water rights holders.

Federal law requires the department to operate Lake Oroville reservoir partly for flood control purposes, which may necessitate releases to provide adequate space in the reservoir to guard against flooding.

Delta water quality and outflow standards may require releases from Lake Oroville to ensure proper flow and water quality for agricultural, municipal, and industrial uses and for the protection of wildlife.

Regulatory licenses or agreements may require DWR to release water from Lake Oroville to protect wildlife.

Source: Federal and state law; DWR licenses, permits, and agreements with water rights holders or federal or state entities; and the *Department of Army Report on Reservoir Regulation for Flood Control for the Sacramento River Basin*.

The Role of the State Water Board

The State Water Resources Control Board (State Water Board) also plays a role in managing water in the State. State law gives the State Water Board responsibilities that include administering water rights and coordinating and controlling water quality. Consequently, the State Water Board established several of the standards that affect DWR's and Reclamation's operation of the State Water Project and Central Valley Project, respectively, including those related to Delta outflow and water quality.[3] The State Water Board does not participate in DWR's development of water supply forecasts. However, several of the water quality standards that the State Water Board has established and that affect the State Water Project and Central Valley Project are connected to DWR's B120 water supply forecasts: during various times of the year, the particular water quality or outflow standard that the State Water Project and Central Valley Project must meet is determined in part by those forecasts. In other words, the State Water Project and Central Valley Project may need to adhere to different standards, depending in part on the amount of water that DWR forecasts in the B120.

The Effects of Climate Change on California's Water Supply

The increasing effects of climate change have had ramifications for the State's water supply. Over the last 15 years, the State has experienced extreme weather conditions, including multiple droughts and periods of flooding. In October 2022, DWR reported that water years 2020 through 2022 represented the driest three-year period on record, breaking the record previously established from 2013 through 2015. The severity of the drought led the Governor to proclaim a state of emergency in October 2021, and the State Water Board issued orders imposing water rights curtailments. These temporary curtailments prohibited various water rights holders from diverting water when the Board determined that the water supply was insufficient to support their particular water rights. Further demonstrating the potential for sudden and significant shifts in weather conditions, the unusually dry conditions from 2020 through 2022 have been followed by significantly higher-than-average precipitation and snowpack during water year 2023, as well as storms and flooding.

Climate researchers project that the effects of climate change will continue to increase, causing greater fluctuation in rainfall patterns and severe weather—including prolonged drought. Hotter temperatures dry out the soil through increased evaporation and reduce the amount of snow in the mountains, both of which can lessen the subsequent spring runoff. At the same time, DWR has projected that rising sea levels could increase the intrusion of salt into the Delta, requiring the release of more water to protect water quality. In an October 2008 report, DWR stated that climate change had already had a profound impact on water resources, and it pledged to play a leadership role in adapting to those impacts.

[3] For the sake of simplicity, we use the term "standards" throughout this report to refer to water quality standards and objectives implemented by State Water Board Decision 1641 and certain other requirements governing State Water Project operations.

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DWR Has Not Adequately Ensured That Its Water Supply Forecasts Account for the Effects of Climate Change

Key Points

- In water year 2021, DWR significantly overestimated the water supply as late as its April B120 forecasts. Large errors in DWR's forecasts can affect state and local efforts to effectively manage the water supply.
- Despite acknowledging the need to do so more than a decade ago, DWR has not fully updated its forecasting model and related procedures to better account for the effects of climate change. Some other federal and local agencies use models that directly account for factors that are relevant to climate change, such as temperature and soil moisture.
- DWR lacks a formal process for evaluating its forecasting model. Such a process could help DWR identify opportunities to improve the model and related procedures to produce more accurate forecasts.

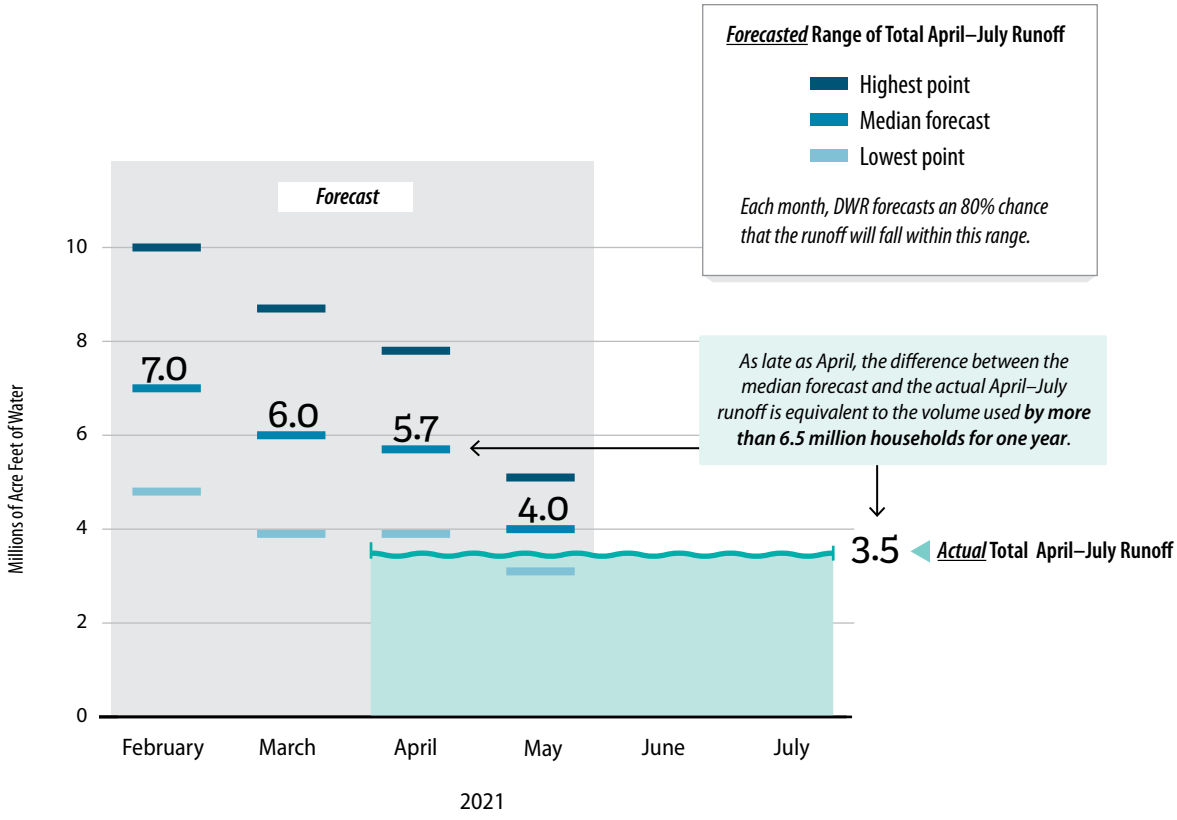
DWR Significantly Overestimated the 2021 Water Supply

For water years 2017 through 2021, we reviewed DWR's B120 forecasts of the total April through July runoff in each watershed for which it develops forecasts. In water year 2021, which DWR later noted was an extreme year, DWR's median forecasts in its initial February B120 report projected that runoff would be at least twice the volume that actually occurred for the majority of those watersheds. This average error rate of more than 100 percent, as measured across all of the forecasts that we reviewed, was significantly higher than the average error rate of DWR's median forecasts during the previous four years, which ranged from about 20 percent to about 50 percent.

As an example, Figure 3 displays the error rate in DWR's 2021 median forecasts for two important regions—Sacramento and San Joaquin. Together, these two regions help supply fresh water, via the Delta, to two-thirds of the State's population, as well as to thousands of square miles of agriculture. As the figure shows, DWR's error rate was still significant as late as April 2021, a month before its final B120 forecast. In fact, even the lower limits of DWR's probability range at that point overestimated actual runoff by 385,000 acre feet. The actual runoff did not fall within DWR's probability range until it further reduced its forecast for its final B120 in May.

Figure 3
DWR Significantly Overestimated the State's 2021 Water Supply as Late as April 2021

The chart below shows the magnitude of the errors in DWR's forecasts for two key regions, the Sacramento Valley and San Joaquin Valley.



Source: DWR's water supply forecasting procedures, B120 water supply forecasts, and actual runoff calculations.

As we describe in the Introduction, the volume of runoff DWR projects in its B120 forecasts can affect the State Water Project's releases of water to protect water quality and its determinations about how much water will be provided to certain water rights holders. We reviewed a range of State Water Project requirements that are influenced by the B120 forecasts, including several that are affected in particular by DWR's median forecast. In general, the latter requirements are determined by a calculation called the *Sacramento Valley Water Year Hydrologic Classification Index* (Sacramento Valley Index), which DWR publishes in its February B120 forecast and updates each month through May. DWR calculates the Sacramento Valley Index according to measured and estimated current water year runoff, the previous water year's Sacramento Valley Index, and the median forecast for four locations in the Sacramento River region. This calculation results in a classification for the water year—such as *wet*, *dry*, or *critical*—that in turn triggers certain water management requirements.

Despite the high error rate in DWR's forecasts for water year 2021, the error rate did not ultimately affect the Sacramento Valley Index water year classification and the corresponding requirements on the State Water Project. Due to dry conditions during water year 2020, which were present again as of February of water year 2021, DWR's initial B120 forecast included a Sacramento Valley Index classification of *critical* for the year—the lowest classification in terms of runoff. DWR's subsequent downward revisions to its forecasts did not change the water year classification because DWR was already expecting the water year to be in its lowest tier. Therefore, DWR's forecasting error fortunately did not result in a misclassification of the water year that would have required the State Water Project and Central Valley Project to meet stricter Delta water quality and outflow standards. However, under different circumstances, the magnitude of DWR's forecasting error could have led to a misclassification of the Sacramento Valley Index, thereby potentially requiring the projects to release more water from their reservoirs or export less water from the Delta. As we discuss later in the report, we identified months in water year 2021 during which DWR released more water than required by certain water flow standards, but for which it could not provide sufficient documentation to explain.

Inaccuracies in DWR's B120 forecasts can also affect some local water agencies' management of their own reservoir water supply. For example, we reviewed three federal hydroelectric project-related licenses that require certain local dam operators to maintain a minimum amount of streamflow for the protection of wildlife, based on particular DWR forecasts. Maintaining that minimum streamflow may require the dam operators to release certain volumes of water, and generally, higher forecasts dictate higher required releases of water. In all three licenses, the requirements on dam operators are affected not just by DWR's May B120 forecast, but also by its earlier forecasts. In two of the licenses, requirements are based specifically on DWR's median forecasts—one on the February B120 forecast and the other on the April B120 forecast.

DWR's water year 2021 forecast error affected at least some local water agency requirements. El Dorado Irrigation District's license to operate its hydroelectric project establishes the minimum streamflow requirements from the district's dams according to DWR's monthly median forecasts of inflow into Lake Folsom, starting with its February B120 forecast. DWR's overestimation of the inflow for Lake Folsom established higher required streamflow levels for El Dorado Irrigation District's operations than would have been required if DWR's forecast had been more accurate. The director of operations for the district indicated that, because of DWR's April 2021 overestimation of projected runoff, the district had to forego diverting water into storage that it would have otherwise been able to capture in its reservoir. He estimated that the district was unable to divert 925 acre feet of water, or about the amount of water used by 2,750 households over a full year. As this example demonstrates, significant errors in DWR's forecasts can affect other entities' efforts to effectively manage the State's finite water supply.

When explaining the inaccuracies in its 2021 forecasts, DWR referenced the effects of climate change. In a September 2021 report about water year 2021, DWR noted that, although snowpack levels were about 60 percent of average, the ultimate streamflow within major Central Valley watersheds was significantly lower than the amount of snow would suggest. The report further explained that prolonged warm and dry conditions created a moisture deficit in the climate system, reducing runoff efficiency. The manager

of DWR's hydrology section also explained to us that wildfires and hot, dry conditions in 2020 dried the soil and cleared a lot of vegetation. He indicated that, as a result, the soil absorbed the 2021 spring snow melt and that much of the winter snowfall did not make it down the mountains to flow into rivers and reservoirs. In May 2021, DWR rapidly decreased its forecasts by more than 25 percent from its April levels and noted that runoff to date had been significantly below average.

As we acknowledge in the Introduction, hotter temperatures and extreme weather conditions have affected the State's water supply. Indeed, DWR publicly reported that its significant overestimation in its spring 2021 forecasts illustrates the importance of shifting away from its statistical approaches that rely on a historical record that is no longer reflective of observed conditions. However, as we describe in the following section, DWR has made only limited progress toward adopting and implementing a forecasting model that can better account for the effects of a changing climate.

DWR Has Not Fully Implemented Changes to Its Water Supply Forecasting Model and Procedures to Account for the Effects of Climate Change

DWR has known for over a decade that it must adjust its surface water forecasting methods to account for the effects of climate change. In an October 2008 report on climate change adaptation strategies, DWR stated that climate change was already affecting the State's water resources and increasing uncertainty for the water supply. The report specifically cited the State's changing rain and runoff patterns. DWR further explained that historical patterns could no longer be solely relied upon to forecast the water future and that, going forward, water supply forecasting model calibration must happen more frequently and new forecasting tools must be developed. DWR concluded that a standard of practice that explicitly considers climate change must be adopted. Similarly, DWR noted in a 2018 presentation that its forecasting errors had increased for most basins between 1997 and 2018. DWR once again referenced climate change, indicating that it might be causing the increasing errors.

However, DWR still has not fully adopted a new model and associated procedures for developing its B120 water supply forecasts.[4] DWR's current model is a statistical equation that uses the most recent data DWR has on observed precipitation, snow levels, and runoff. DWR also incorporates estimates of likely future precipitation, snow, and runoff until observed data becomes available. DWR generally uses historical medians to develop its future estimates, entering the observed and estimated data into a statistical equation that predicts the total amount of runoff based on historical runoff patterns. As a result, DWR's forecasting model relies heavily on historical weather and runoff behaviors.

In contrast to DWR, some local and federal agencies use forecasting models that leverage additional data that may allow them to better account for the changing climate and its effects on the water supply. We reviewed the water supply forecast

[4] At the end of April 2023, DWR stated that it was continuing to make progress on its efforts toward fully adopting new forecasting procedures during the current water year; however, because of the timing of this information, we will assess its progress when DWR provides its updates on the implementation of our recommendations.

models used by four other agencies: the Turlock Irrigation District (Turlock), the San Francisco Public Utilities Commission (San Francisco), the Merced Irrigation District (Merced), and the California Nevada River Forecast Center (CNRFC).[5] Although the specific models the agencies use differ, each agency's model incorporates observed or modeled data that is relevant to climate change, such as temperature and soil moisture. DWR's forecasting model does not incorporate modeled or observed data on those same factors.

As part of our review of other agencies' forecasting models, we compared the accuracy of their forecasts to DWR's forecasts for water years 2017 through 2021, to the extent that they were available. Of the four agencies we reviewed, two could provide records of their historical water supply forecasts from before water year 2022: CNRFC and Turlock.[6] We reviewed the median forecasts that the two agencies provided and found that both agencies overestimated the 2021 water supply and that Turlock did not have consistently lower error rates than DWR. Although CNRFC's initial forecasts for the five years we reviewed started out with roughly the same average error rate as DWR's, CNRFC's forecasts became more accurate than DWR's in subsequent months, as Figure 4 shows. For example, in water year 2021, CNRFC adjusted its forecasts downward during the water year to account for the dry conditions much more quickly than DWR did.

Email records from March 2021 show that DWR staff contacted CNRFC to understand why its forecasts were so much lower than DWR's. Through those emails, CNRFC staff explained to DWR that the difference was likely because CNRFC's forecasting model accounted for the abnormally dry soil moisture levels in the State. CNRFC uses a model called the *hydrologic ensemble forecast service* that incorporates observed and forecasted data, including precipitation and air temperature, and also accounts for other hydrologic processes, such as soil moisture and the effect of rain on snow. The emails further show that in response to the information from CNRFC, DWR attempted to adjust its own model to account for the soil moisture data but struggled to do so—likely because its model is not designed to directly incorporate those data.

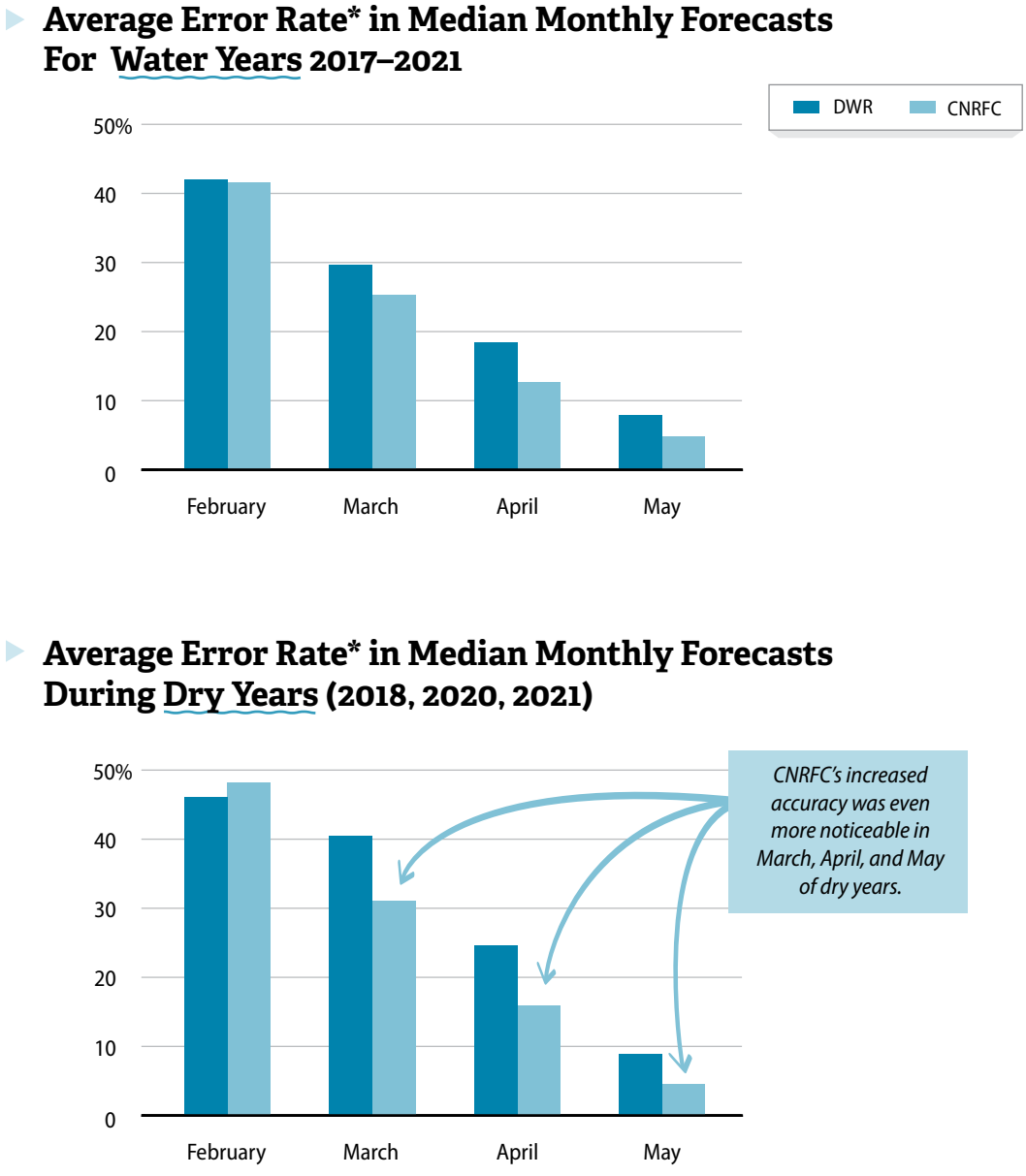
Although other agencies have incorporated additional data into their forecasting, DWR has made only limited progress toward adopting and implementing a forecasting model that can better account for the effects of a changing climate. In response to our request for records related to its efforts to adapt its forecasting model, staff at DWR pointed us to multiple different models and collaborative efforts with the University of California (UC) and other entities. However, the majority of these efforts either focused on evaluating or developing models for other purposes, such as predicting extreme flooding events, or began after the water year 2021 forecasting season. In fact, the records we reviewed suggest that before water year 2021, DWR made only one formal attempt to adopt another water supply forecasting model. Specifically, in 2010 it contracted with the U.S. Geological Survey (Geological Survey) to, among other things, develop new forecasting models for selected watersheds.

[5] CNRFC is a field office of the National Weather Service, which is an agency of the National Oceanic and Atmospheric Administration.

[6] At the time of our audit, San Francisco was still in the process of calibrating its new model and had not yet transitioned completely to using it to produce its forecasts. Merced's formal water supply forecasts were not readily available for our review.

However, DWR confirmed that its efforts to develop those models ended in April 2019. The manager of DWR's hydrology section explained that DWR stopped pursuing those models because they were taking too long to develop and because DWR determined that the complexity of running and updating the models made them impractical to use.

Figure 4
For the Past Five Years, CNRFC's Median Water Supply Forecasts Have Had a Lower Average Error Rate Than DWR's Median Forecasts



Source: DWR's B120 water supply forecasts and reports on actual flow, and CNRFC ensemble forecasts.

* The error rate is the difference between the forecast and actual April-through-July runoff as a percentage of the actual April through July runoff.

Because of DWR's limited progress in updating its forecasting model, its own forecasts have not fully benefitted from another substantive effort that the department made before water year 2021 to improve water supply forecasting in the State more broadly. Specifically, in March 2013 DWR began partnering with the National Aeronautics and Space Administration (NASA) to fund observatory flights to measure the water volume of snow in the Sierra at selected locations. In its contract with NASA, DWR noted that the conventional approach to measuring volumes of water in snow did not provide sufficiently accurate data and that the observatory flights would provide water managers with the ability to more accurately forecast the timing of snow melt. DWR continues to fund flights over nine watersheds, including the Merced and Tuolumne watersheds. One local agency told us that it has begun inputting the data from those flights directly into its water supply forecasting model, and another agency is using it to evaluate the modeled data its forecast produces. Despite the noted benefits that these flights provide, the manager of DWR's forecasting unit stated that the data from the flights cannot be incorporated into its model; instead, DWR staff review the data and the modeled results from the flights and then make some manual adjustments to snow measurements, based on the staff's experience.

Following the significant error in its water year 2021 B120 forecasts, DWR took steps intended to improve its forecasting. It contracted with different entities to use various tools and models to support its water supply forecasting, as the text box shows. For example, DWR contracted with UC Davis in the fall of 2021 to expand on a model for extreme weather events by, among other things, incorporating weather and climate forecasts from the National Oceanic and Atmospheric Administration (NOAA) to produce water supply forecasts. These efforts are consistent with a plan that DWR drafted later, between the summer and fall of 2022, for adopting various technologies and observational methods to make its forecasting more resilient to the effects of climate change. It finalized this plan in March of 2023. The plan states that one of DWR's forecasting goals is to transition to modeling tools that are physically based and climate-informed, such as models that simulate the physical process of snow accumulation and melt.

Key Contracts DWR Has Entered Into to Improve Its B120 Forecasts

- **September 2021:** Contracted with UC San Diego to develop an experimental forecast system using machine learning and hydrologic modeling that tracks soil moisture, weather, and other factors, in an effort to modernize the B120 forecast process.
- **October 2021:** Contracted with UC Davis to expand on a model for extreme weather events to produce water supply forecasts that incorporate NOAA's weather and climate forecasts, and to train DWR staff on the model's use.
- **March 2022:** Contracted with a firm for continued snow observatory flights over areas for which it produces B120 forecasts. The contract also covers snow and hydrologic modeling to provide data and models for use in producing forecasts, including soil moisture and snowmelt.

Source: DWR contracts.

Additionally, the manager of the forecasting unit stated that DWR piloted a new model for forecasts in certain watersheds in water year 2022, and DWR provided documentation of some of the model's early results. DWR's plan indicates that its goal is to transition to the new model to create water supply forecasts by water year 2025, which begins in October 2024. The manager of DWR's forecasting unit explained that DWR needs until water year 2025 to calibrate and validate the effectiveness of the new model, as well as to train its staff on its use.

Yet DWR's plan does not include any accountability mechanisms to ensure that it implements its new model promptly. Further, although the plan includes the objective of developing forecast model performance tools, it does not contain specific criteria for determining whether the new model is sufficiently accurate for use. The manager of the forecasting unit described criteria that he indicated DWR is considering in evaluating the new model, which include the timeliness with which the model produces results and the ability of the model to produce reliable results in different types of watersheds. However, he confirmed that DWR has not yet established more specific criteria for how accurately it expects its model to perform. Until its new model is operational, DWR plans to continue to generate its forecasts using its existing methods, although it told us that it narrowed the historical data it uses from a 50-year period to the most recent 30 years, to better reflect the current climate.

When we asked why DWR had delayed pursuing improvements to its forecasting model to account for the effects of climate change, the manager of the forecasting unit disagreed that it had done so. He stated that DWR had worked tirelessly for years to develop and evaluate the models that it had contracted with the Geological Survey in 2010 to develop, an effort that we describe earlier. However, DWR has acknowledged that its significant overestimation in its spring 2021 forecasts illustrates the importance of shifting away from statistical approaches that rely on historical records that no longer reflect observed conditions.

DWR Needs a Formal Process for Monitoring and Improving the Quality of Its Forecasts

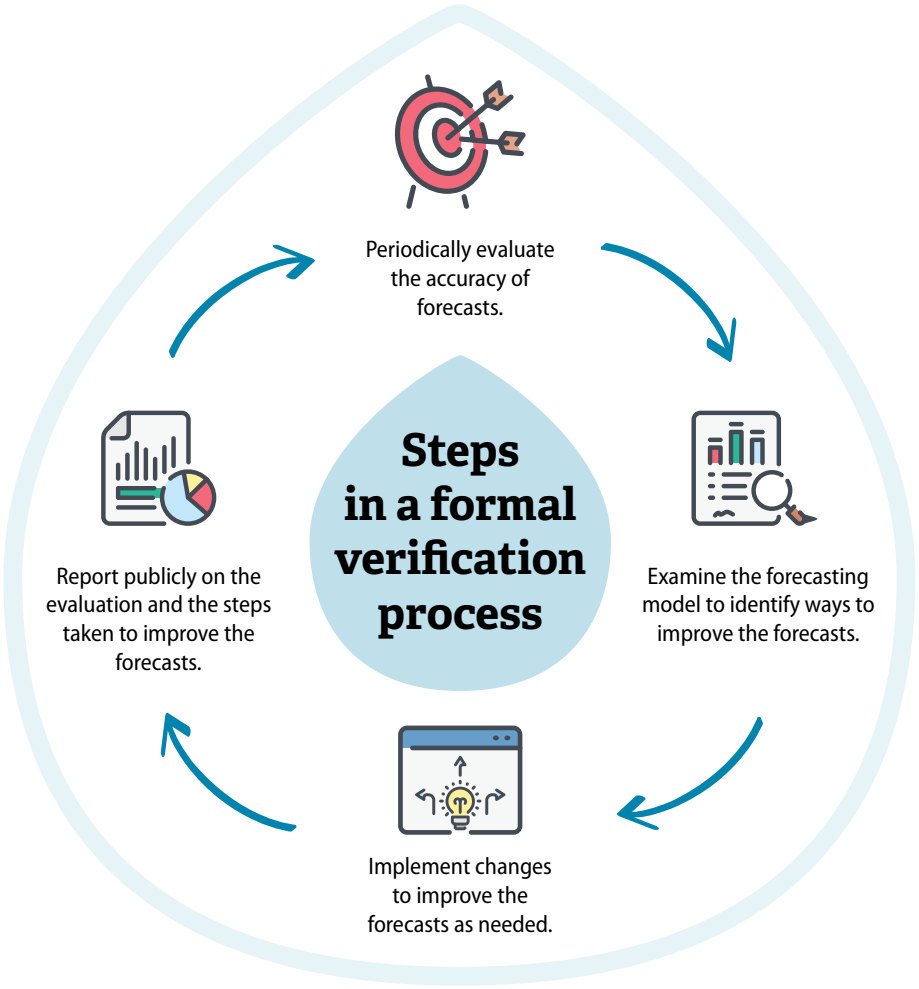
Despite the importance of its B120 forecasts, DWR does not have a formal process for evaluating its forecasting model or the accuracy of its forecasts. According to the National Center for Atmospheric Research (NCAR), every activity focused on providing forecasts to users should have an associated verification activity to monitor the performance of the system and identify possible improvements. As Figure 5 shows, forecast verification is an iterative process for assessing forecast accuracy that allows for systematic and objective evaluation of the quality of a forecasting system. DWR could benefit from a formalized verification process through which it regularly evaluates the quality of its forecasts by comparing its water supply forecasts to the actual, observed water supply. After doing so, DWR could then use the results of that evaluation to examine its forecasting model and identify any opportunities for improvement. However, DWR does not currently have a formal verification process in place.

The manager of the forecasting unit asserted that although DWR has not established a formal process for continuously improving its forecast, the forecasting unit constantly reviews and evaluates its forecasting model. He indicated that whenever reasonable, the forecasting unit creates new statistical equations for the model and recomputes the data that the model uses to ensure that the forecasting unit is using the most up-to-date information. The documentation he provided shows that DWR has developed different variations on its existing model and has compared its probability range and median forecast to actual runoff.

However, that documentation did not demonstrate that DWR has implemented a formal verification process in accordance with the best practices we reviewed. Best practices from meteorological and water supply forecasting organizations contain multiple methods of evaluating a forecast's accuracy, each of which may provide different insight into the quality of the forecast and the nature of forecast errors. For instance, guidance from the World Weather Research Program describes several methods relevant to assessing the quality

of a forecast, such as its relative accuracy over other forecasts or its tendency to under- or overforecast outcomes. However, in the examples DWR provided of its evaluations efforts, it typically used only one or two methods to evaluate its forecasts each time. For example, the assessment DWR provided of its water year 2021 forecast displayed the observed runoff compared to the probability range and its median forecast. By contrast, CNRFC reviewed its forecasting model using five different statistical metrics for a simulated 26-year period and then compared the results of those metrics to one another. These evaluations allowed CNRFC to make detailed assessments about the performance of its forecasting model, such as whether its median forecast tended to over- or underforecast the water supply, how the model performed in years that were wet versus dry, and how the model performed in extreme conditions. Such assessments were generally absent from the evaluation documentation that DWR provided. Performing additional analyses similar to CNRFC's analyses could provide DWR with additional useful information about the performance of its forecasting model and specific areas of needed improvement.

Figure 5
A Formal Verification Process Allows for Systematic and Objective Evaluation of a Forecasting System


Steps in a formal verification process
Periodically evaluate the accuracy of forecasts.
Examine the forecasting model to identify ways to improve the forecasts.
Implement changes to improve the forecasts as needed.
Report publicly on the evaluation and the steps taken to improve the forecasts.

Source: Best practices from CNRFC, NRCS, NCAR, the World Meteorological Organization, and verification research.

Additionally, the records contained little information about DWR's conclusions regarding the possible causes of the forecast errors it identified or improvements it planned to make. We were able to identify evidence of DWR's considering the cause of the forecast errors only in the 2018 presentation materials, which stated that the increase in the errors in its forecasts over the preceding decade "could be due to climate change." Although DWR also described reevaluating and adjusting its forecast model equations after the 2018 presentation, the documentation it provided indicates a stand-alone effort and not a formal, recurring evaluation process.

Further, guidance from the Natural Resources Conservation Service (NRCS)—which develops the water supply forecasts for 13 western states—explains that forecast verification should be conducted each year once data on actual runoff is available. A formal process that outlines the specific methods that DWR will use to evaluate its forecasts and describes how DWR will use the outcomes of that evaluation to improve its forecasts may help DWR to better ensure ongoing improvement in its forecasts' predictive capability.

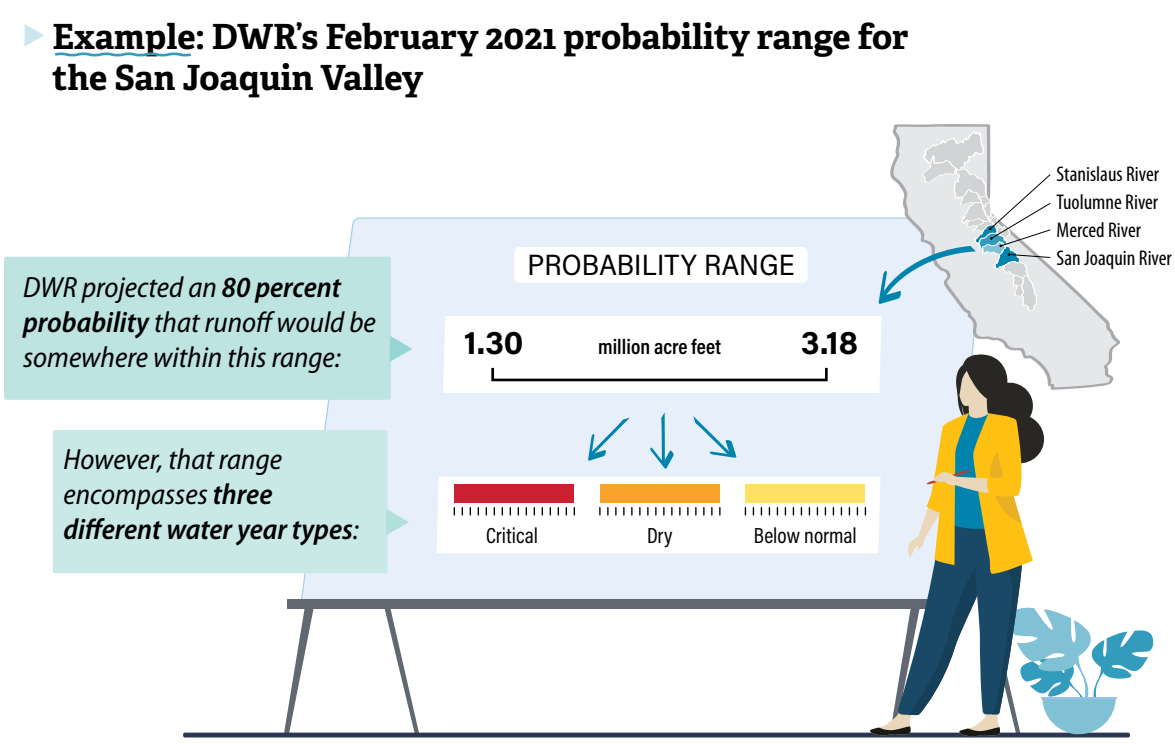
DWR should also reevaluate the criteria by which it judges the success of its forecasts. The manager of the forecasting unit explained that DWR's formal accuracy goal for its monthly forecasts is that observed water supply falls within each forecast's probability range. The probability range can be valuable to water managers because it provides them with a broader understanding of possible water supply volumes and enables risk-based decision making. However, determining whether the observed runoff falls within the entire probability range is not sufficient as the sole measure of the quality of DWR's forecasts. NRCS guidance indicates that it is important to know more specifically where actual runoff falls relative to a probability range. Consistently analyzing and documenting this information could help DWR assess the degree to which actual runoff is consistent with or deviates from its forecasts' expected outcomes. NRCS indicates that, to the extent necessary, this type of measurement may help lead to model refinements in preparation for the next season.

Additionally, DWR's probability ranges can be broad, particularly earlier in the water year. As Figure 6 shows, DWR's probability range in its water supply index for the San Joaquin Valley in February 2021 was so broad that it encompassed three different water year classifications for the area—*critical*, *dry*, and *below normal*. Therefore, a forecast with a wide probability range could successfully predict the eventual runoff while still not providing much certainty to the forecast's users. Indeed, the manager of the forecasting unit also stated that DWR's goal is to forecast as accurately as possible as early in the season as possible. Using multiple methods to evaluate accuracy simultaneously, as we describe above, might allow DWR to reach more nuanced, but potentially important, conclusions about its forecasts.

A comprehensive evaluation of DWR's forecasting accuracy should also include an analysis of its median forecast. The manager of the forecasting unit expressed concerns about an evaluation that focuses only on the median forecasts, asserting that it would be misleading. He emphasized that DWR publishes its forecast as a probability range. However, one of the indicators of forecast quality is the degree to which a forecast benefits decision makers. The median forecast has important implications for the management of the State Water Project as well as for the

requirements that certain local water management agencies must meet. Further, both CNRFC and NRCS describe evaluating the accuracy of their median forecasts, and the documents DWR provided to demonstrate its past evaluation efforts show that it used its median forecast in those efforts.

Figure 6
DWR's Runoff Probability Ranges Can Be Broad, Limiting Their Usefulness as the Sole Measure of Its Forecasts' Accuracy



Source: DWR's water supply forecasts and indices.

The manager of the forecasting unit agreed that documenting a formal process for evaluating the quality of DWR's forecasts would be beneficial and would provide transparency about the department's efforts to improve its forecasts. He also acknowledged that although DWR intends to keep the probability range as the main criteria for verifying its forecasts, it will not limit its review to that single metric; he stated that DWR would instead use various statistical charts and graphics that it would post to its website. However, DWR had not yet established criteria or a methodology for its review. A formal process that requires consistent, thorough evaluation of its forecasts' accuracy would assist DWR in more proactively taking the steps necessary to make those forecasts as accurate as possible.

Please refer to the section beginning on page 3 to find the recommendations that we have made as a result of these audit findings.

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DWR Must Do More to Prepare for the Impact of More Severe Droughts on the State Water Project's Operations

Key Points

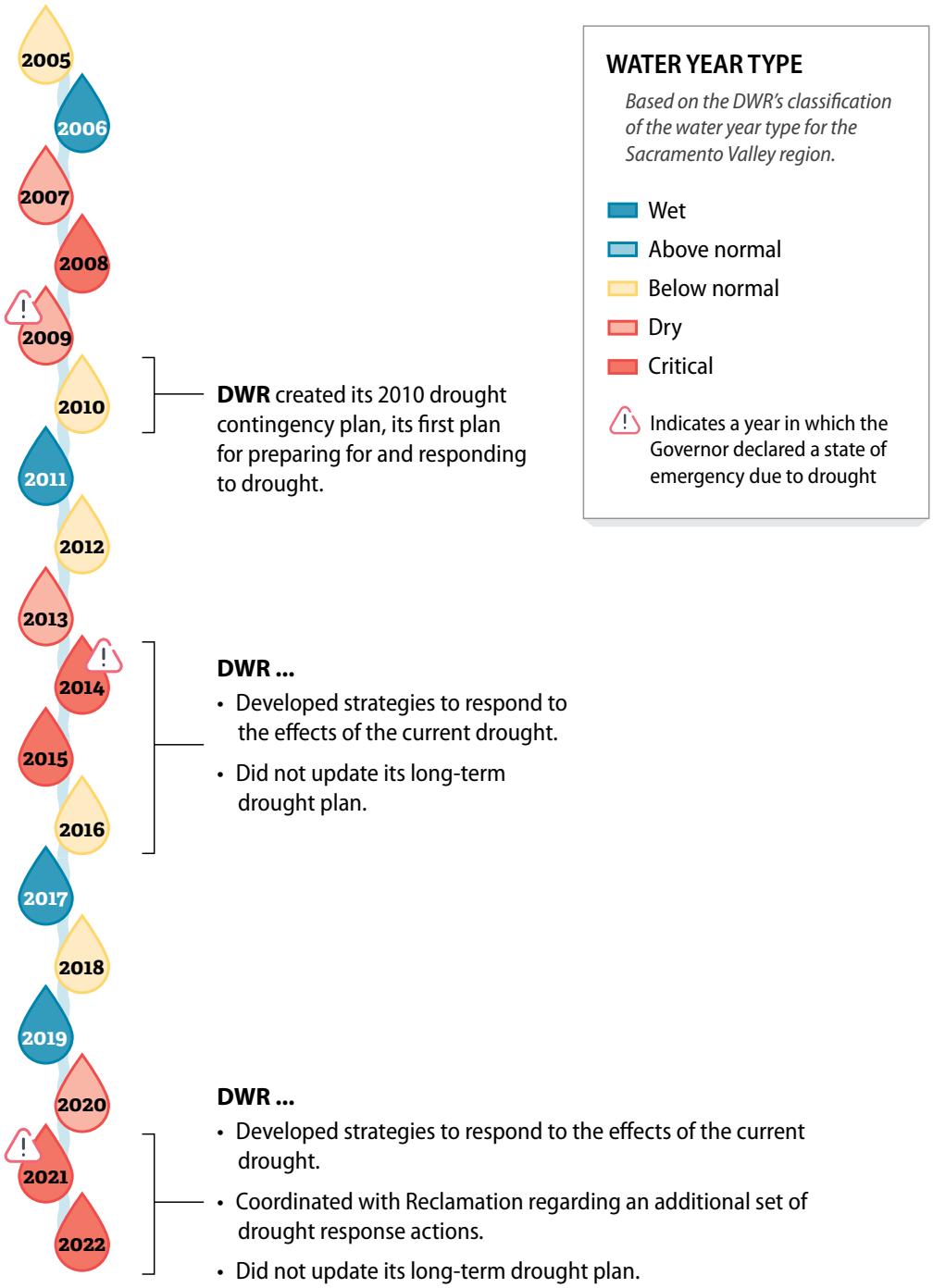
- DWR does not have a comprehensive, long-term plan for identifying, mitigating, or responding to the effects of more severe future droughts on the State Water Project.
- Whether planned or in reaction to conditions in the Delta, DWR's decisions to release water from the Lake Oroville reservoir have important implications for water stakeholders and the public. However, DWR has not consistently documented the reasons for its planned and actual water releases.
- DWR has not accounted for the possibility of more extreme future conditions when it develops its monthly water allocation analysis and water storage target for the Lake Oroville reservoir.
- DWR lacks a formal process for periodically evaluating certain State Water Project operations to identify opportunities for improvement.

DWR Does Not Have a Comprehensive, Long-Term Plan for Mitigating or Responding to the Effects of More Severe Drought on the State Water Project

Millions of California's residents and 750,000 acres of its farmland depend on the State Water Project—a water storage and delivery system that collects surface water from the northern part of the State and delivers it to both the Bay Area and Southern California. Given the importance of the State Water Project to California, DWR's effective management of the project's operations is essential. Moreover, this need for effective management is becoming more critical as climate change threatens to increase the frequency, duration, and severity of droughts. DWR itself has concluded that long-term hydrologic changes caused by climate change pose serious challenges to its operation of the State Water Project.

Best practices from the Federal Emergency Management Agency (FEMA) and from the National Drought Mitigation Center (NDMC) indicate that agencies should develop long-term plans for mitigating and responding to hazards, such as droughts, before they happen. The guidance further suggests that doing so can help reduce the impact of droughts. However, DWR did not develop its first long-term drought plan, the 2010 Drought Contingency Plan (2010 drought plan), until November 2010, more than two years after the 2008 statewide drought had been declared. The 2010 drought plan contains potential actions by DWR and other agencies to prepare for drought, including some that are relevant to the State Water Project. At the time, DWR indicated that it intended to update the plan every five years. As Figure 7 shows, DWR has not done so, nor has it developed any other comprehensive long-term plan for managing State Water Project operations during droughts.

Figure 7
Rather Than Updating Its Long-Term Drought Plan, DWR Has Instead Developed Short-Term Strategies During Critically Dry Periods



Source: DWR data on water year types, drought contingency plans and strategies, and Drought Toolkit, and governor executive orders pertaining to drought from 2007 through 2022.

Instead, DWR has documented drought-related strategies for managing State Water Project operations only after dry conditions have already occurred. Under the terms of a 2020 permit it received from the California Department of Fish and Wildlife, DWR must, in coordination with Reclamation, develop a drought contingency plan (contingency plan) when the previous two years' water supply falls below a certain threshold.[7] If dry conditions continue, DWR and Reclamation must update the contingency plan each month based on hydrologic conditions. The contingency plans contain response strategies that describe how DWR and Reclamation will jointly manage the limited water supply to meet their various objectives, such as meeting water quality standards in the Delta and making deliveries to State Water Project and Central Valley Project contractors.

DWR's response strategies are specific to the immediate conditions and do not include the type of long-term planning to prepare for future droughts that best practices recommend. For example, in a contingency plan that DWR developed after the Governor declared a state of emergency because of drought in 2014, DWR stated that the purpose of the plan was to provide an overview of current conditions and to address projected water operations over a three-month period. Its next contingency plan, which it published at the end of that three-month period, described the same purpose for responding to the ongoing drought. These documents play roles in responding to acute conditions that have already arisen, but they do not look beyond the circumstances under which they were created.

By not updating its 2010 drought plan in more than a decade, DWR has missed opportunities to incorporate into the plan the lessons learned from the significant drought and dry periods that occurred during that time. FEMA and NDMC both recommend that an agency reevaluate and update its plans periodically, as well as after each drought. Their guidance indicates that evaluation of plans allows an agency to incorporate lessons learned from past droughts. Further, NDMC's guidance states that without post-drought evaluations, learning from past successes and mistakes is difficult, as institutional memory fades. However, DWR did not update its 2010 drought plan even after the period from 2013 through 2015, which it later identified as having been the driest in recorded history to that point. For example, DWR's 2010 plan includes a potential drought response action that calls for it to lead the development of a program for temporary transfers of water for instream flows to protect native fish and sports fisheries. Because DWR has not updated the plan, it does not make clear whether DWR implemented this action during subsequent droughts and, if so, whether the action was successful and whether adjustments to the program are necessary.

In addition to being outdated, DWR's 2010 drought plan does not incorporate the assessment of more severe future droughts as FEMA and NDMC recommend. Those entities suggest that after an agency considers the potential effects of a more severe drought than it has historically faced, it should then assess its ability to respond to these impacts, identify any gaps in its ability, and determine what it can do to

[7] The permit is DWR's Incidental Take Permit for long-term operation of the State Water Project in the Delta. The permit establishes certain requirements on DWR's operation of the State Water Project, including limiting exports of water at certain times for the protection of threatened and endangered wildlife.

address the gaps. Its drought planning should describe the actions the agency will take to respond to the identified impacts of drought and include specific triggers for when the agency will initiate those actions.

In addition, FEMA's guidance on planning for hazards, including drought, recommends that an agency should assess how a changing climate is affecting the frequency and intensity of those hazards. The guidance notes that understanding the potential future effects of climate change may require the creation of plans that are flexible and scalable. As early as 2008, DWR itself has advised local agencies that they should plan for droughts that are at least 20 percent more frequent and longer lasting than droughts in the past. For its part, the 2010 drought plan states that warming, changes in precipitation, and increases in extreme events—including drought—are expected to affect the functioning of ecosystems. It further states that reduced snowpack, changes in water flows, and other effects will have negative effects on many native species. However, the plan does not identify how the expected, more severe impacts of drought may specifically strain the State Water Project's responsibilities to meet water quality and flow standards for the protection of wildlife. It also does not describe whether DWR may need to take new actions to address these more severe impacts or the challenges it might face in doing so.

DWR's manager of water operations stated that she was not aware of specific plans to prepare the State Water Project for droughts that are more severe than past droughts. She also explained more generally that State Water Project drought planning has taken place and continues to take place through more focused planning efforts, including the response strategies we describe above. We reviewed those response strategies and several other documents DWR provided, such as the Drought Toolkit. Published by Reclamation in August 2021 in collaboration with DWR and other agencies, the Drought Toolkit contains a set of potential drought actions for DWR, Reclamation, and other agencies, such as the California Department of Fish and Wildlife. However, the documents we reviewed do not—even collectively—address all of the elements of best practices. Some contain high-level discussions of certain impacts of drought, and some describe actions that DWR may take when managing the State Water Project during a drought. However, none of the documents sufficiently assess the potential impacts of more severe future droughts on State Water Project operations or the degree to which such droughts may challenge DWR's ability to meet the project's objectives. They also do not contain clear steps that DWR intends to take to address those challenges.

For example, DWR pointed to its delivery capability reports as evidence of its drought-planning efforts. These reports provide information to State Water Project contractors about the project's water delivery capability; they are not themselves plans for operating the State Water Project during a drought. DWR's 2021 delivery capability report noted that DWR recognized the risk posed by climate change to future hydrologic and water supply conditions, and it provided estimates of its capacity to deliver water to its contractors under different scenarios, including during dry years. However, the report does not describe specific anticipated effects of climate change on other key State Water Project operations, such as the potential need to release water from its reservoirs to meet water quality conditions in the Delta. When we shared these observations with DWR, the deputy director

of the State Water Project indicated that although the delivery capability reports do not describe those anticipated effects, the reports still accounted for them because the methodology that DWR used to develop the reports assumes that all of DWR's regulatory requirements and other obligations are met before providing water to State Water Project contractors.

Notwithstanding the analysis DWR describes performing, the reports still lack fundamental elements of a long-term drought plan. For example, the purpose of performing an analysis of drought impacts during drought planning is to inform the development of specific strategies for responding to and mitigating those impacts. However, beyond possible reductions to contractor deliveries, the delivery capability reports do not describe any actions that DWR would take to respond to severe drought, such as adjustments it might make to the volume of water it stores in its reservoirs. The plan also does not describe challenges DWR might face in meeting the project's regulatory requirements or how DWR would respond to those challenges. Indeed, as we describe in the following section, DWR did not always meet its water quality requirements during the period of State Water Project operations we reviewed.

When we raised these concerns, DWR's water operations manager pointed to various actions that DWR has taken to prepare for and respond to drought. Examples of those efforts include the Delta Conveyance Project, a project to construct new conveyance facilities in the Delta to improve the reliability of the water supply in the face of more extreme climate events, including drought. Another effort is the construction of drought salinity barriers—physical obstacles placed in the Delta to assist with maintaining water quality during a drought. These projects may assist the State in mitigating and responding to the effects of drought in practice. However, if DWR had a long-term drought plan, it could specify how and when it would leverage these measures. Further, DWR could better identify whether the measures it is currently undertaking will be sufficient if its planning incorporated an assessment of the full range of impacts that more severe drought may bring and an evaluation of whether it has the capacity to respond.

When we shared these conclusions with DWR, the water operations manager provided us with more documentation that she indicated responded to our concerns. This documentation generally fell into one of three categories, none of which amount to a long-term drought plan for the State Water Project. One document listed various short-term efforts DWR took or planned to take in response to the drought that was ongoing at the time. Others were broader reports from DWR about droughts that have occurred in the State in the past, some of which were published decades ago. Finally, several of the documents concerned processes not directly related to the State Water Project, such as DWR's review of local water agencies' groundwater sustainability plans.

The importance of the State Water Project to California and the extremity of the water conditions the State has faced in the past decade make a strong argument for DWR's development of a comprehensive, consolidated plan. This plan should attempt to anticipate and provide practical solutions to the longer-term challenges the State Water Project is likely to face. In doing so, the plan could not only more

clearly identify the roles played by DWR's efforts to date, such as its salinity barriers and Delta Conveyance Project, but also explain the strategies that DWR will employ in the face of specific challenges it has acknowledged are likely to occur, including increasing salinity in the Delta and the demands of managing reservoir storage in the context of an increasingly variable climate.

DWR Lacks Sufficient Records Explaining Some Releases From Its Lake Oroville Reservoir

As Figure 8 shows, DWR balances multiple demands on State Water Project water. For example, it must decide how much water it will allocate to State Water Project contractors while reserving sufficient water in Lake Oroville to address water quality issues in the Delta. It generally makes these decisions through a monthly planning process, which we describe in more detail below.

In addition to this monthly process, DWR monitors conditions such as precipitation and water quality in the Delta on an ongoing basis to determine whether to adjust its plans. To meet their joint obligations in the Delta, including maintaining water quality, DWR and Reclamation take actions that include increasing or reducing exports from the Delta to change water outflow, operating a gate that can help to prevent saltwater from intruding into the Delta, and changing reservoir releases. As the text box shows, multiple factors influence the volume of water that DWR releases from its Lake Oroville reservoir for these purposes. For example, a 1983 agreement with the California Department of Fish and Wildlife (Fish and Wildlife agreement) establishes a minimum amount of water that DWR must release from Lake Oroville each month for the protection of fish and wildlife.

Key Factors That Influence DWR's Releases From the Lake Oroville Reservoir for Water Quality and Outflow Purposes

- **Minimum required releases:** DWR must maintain a minimum volume of releases from the reservoir for the protection of fish and wildlife.*
- **Water quality in the Delta:** DWR may need to release water to address water quality in the Delta.†
- **Delta outflow:** DWR may need to release water to comply with standards requiring a certain amount of water to flow into and out of the Delta.†
- **Coordination with Reclamation:** DWR and Reclamation are jointly responsible for meeting Delta water quality and flow standards, and they coordinate operations to do so.

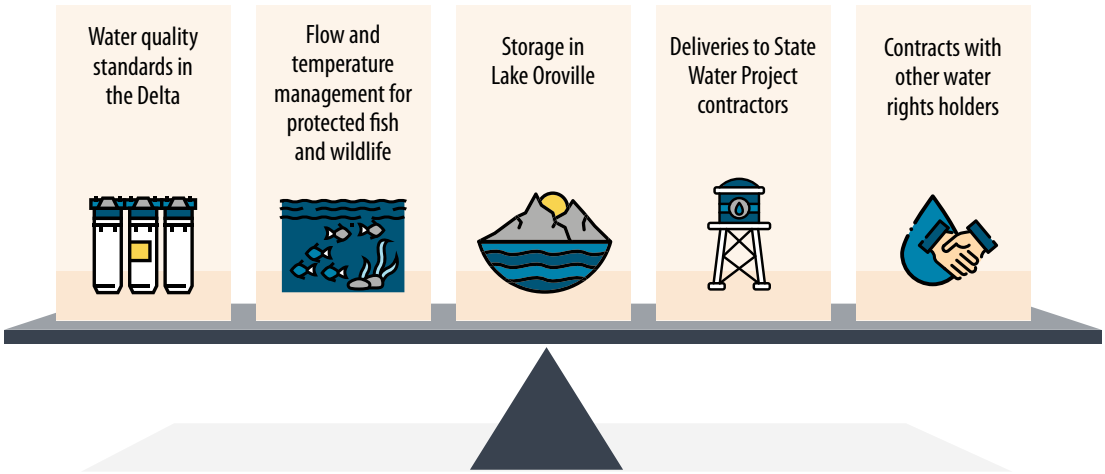
Source: State Water Board Decision 1641; agreement between DWR and the California Department of Fish and Wildlife; and DWR and Reclamation's Agreement for Coordinated Operation of the Central Valley Project and the State Water Project.

* This requirement comes from an agreement between DWR and the California Department of Fish and Wildlife.

† The State Water Board established the Delta water quality and outflow standards.

Whether planned or in reaction to conditions in the Delta, DWR's decisions to release and distribute water affect the volume of water that remains available for delivery to water users, protection of wildlife, and storage for future needs. Given the importance of these decisions and their impacts on different stakeholders, DWR should consistently document the reasoning behind its releases to ensure transparency and to provide water stakeholders and the public greater confidence in its operation of the State Water Project. Consistently documenting the reasoning behind its decisions would also better assist DWR in assessing and evaluating its rationales for its releases.

Figure 8
DWR Balances Various Objectives When Allocating Water From the State Water Project


Water quality standards in the Delta
Flow and temperature management for protected fish and wildlife
Storage in Lake Oroville
Deliveries to State Water Project contractors
Contracts with other water rights holders

Source: Analysis of State Water Project documentation, including State Water Board Decision 1641 and various DWR contracts and agreements.

However, we identified significant gaps in DWR's available records related to its planned and actual water release activities. These gaps limited our ability during the audit to understand and evaluate DWR's water release decisions. Specifically, we reviewed data regarding DWR's releases of water from the Lake Oroville reservoir for a selection of 14 months during water years 2021 and 2022. Through that review, we identified two types of scenarios in which DWR made decisions regarding releases without documenting sufficient justification for its actions. Specifically in some instances, DWR released more water than the minimum required by various standards but did not consistently document how it determined the volume of those releases. In other instances, DWR's lack of documentation inhibited its ability to demonstrate the specific steps it took to ensure water quality.

First, in nine of the 14 months, DWR released more water than the Fish and Wildlife agreement required it to release from Lake Oroville while also allowing more water to flow into the Delta and out to the ocean than related water quality or flow standards required. For example, as Figure 9 shows, DWR released about 153,000 acre feet—or about twice the amount the Fish and Wildlife agreement requires—in October 2020. The releases above the minimum required amounts may have been necessary; however, the records we reviewed for these nine months lacked meaningful details that would reveal DWR's rationale for why its releases were appropriate in scale.

We were unable to verify the appropriateness of DWR's releases because of the vague and limited nature of its planning documentation. DWR maintains two primary types of records that it uses to document its plans for operating the Lake Oroville reservoir. The first is its Delta Coordinated Operation Forecast (allocation analysis), which DWR updates each month and which establishes different sets of options

for meeting its objectives under various water supply scenarios. These options include the amounts of water it may elect to store in its reservoirs, release from Lake Oroville, export from the Delta, and deliver to State Water Project contractors. However, the allocation analysis does not identify DWR's ultimate decisions regarding the options or its rationale for those decisions.

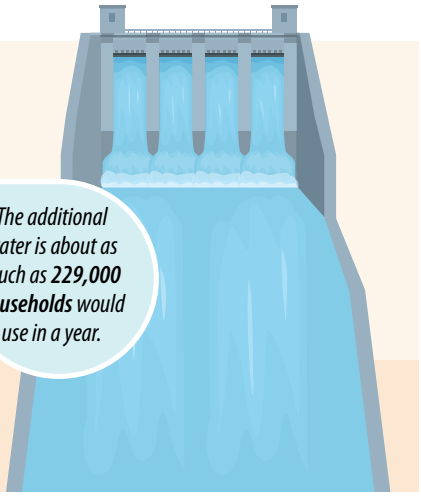
Figure 9
DWR Did Not Adequately Document Its Reasons for Certain Reservoir Releases

In nine of the 14 months we reviewed, DWR released more than the minimum required amount of water from Lake Oroville without documenting its rationale for those releases.

For example, in October 2020 ...

DWR released about 153,000 acre feet of water from Lake Oroville—about twice the amount required by its Fish and Wildlife agreement.

*The additional water is about as much as **229,000 households** would use in a year.*



It also allowed more water to flow out of the Delta than required by flow standards established by the State Water Board.

Complying with water quality standards may require increased releases; however, DWR often lacked documentation showing that this was the case.

DWR generally did not document:

- A written plan for these specific releases.
- A stated rationale for why the amount released was necessary.

DWR needs better documentation to demonstrate its decision making when managing the State Water Project's water supply.

Source: Analysis of DWR's release data, State Water Board Decision 1641, Agreement Concerning the Operation of the Oroville Division of the State Water Project for Management of Fish and Wildlife, and DWR planning documentation.

The second form of monthly planning documentation that DWR provided us was its contingency plans, which we describe earlier and which DWR is required to develop if the water supply falls below a certain threshold during the previous two years. DWR published contingency plans in eight of the 14 months we reviewed. The contingency plans contain records of its release decisions, as well as some rationale for those decisions. However, the rationales that DWR included in the contingency plans often lacked specificity. For example, in May 2021, DWR released 120,000 acre feet—more than double the minimum amount required by the Fish and Wildlife agreement. The additional releases represent enough water to supply about 210,000 households for one year. However, the plan did not contain specific explanations about the need for the volumes of releases, stating instead that DWR expected "that slightly higher outflow will be needed, in combination with the minimal exports, to maintain sufficiently low salinity in the Delta." The plan also indicated that DWR's primary objective was to maintain the lowest possible releases in order to conserve storage. In contrast, we expected to see a discussion in DWR's records about how it determined that this specific volume of additional water was necessary, as opposed to less or even more water.

DWR could provide even less documentation about its rationale for five of the nine months in which it released more water than the minimum required by its Fish and Wildlife agreement while also allowing more water to flow out of the Delta than required by outflow or water quality standards. Across all five months, DWR released almost 200,000 acre feet of water, or about 57 percent, more than the minimum amount required by the agreement. DWR did not publish a contingency plan during those months, and the water operations manager noted that it was not required to do so under the terms of the permit that requires it to develop those plans. Consequently, it has limited record of the specific reasons for its releases or documentation of whether it considered alternatives to the magnitude of these releases, such as adjusting the amount of water it exported from the Delta during those months.

We acknowledge that these significant additional releases may have been necessary to maintain appropriate water quality and flow in the Delta. However, DWR's limited and, at times, absent documentation prevents external parties—including auditors—from evaluating or understanding its decision making. For example, in January 2021 DWR exceeded the minimum releases from Lake Oroville required by the Fish and Wildlife agreement by more than 18,000 acre feet, or about 30 percent, but it could provide no internal records explaining why it did so. The additional volume of water that DWR released is enough to supply water for about 54,000 households for one year.

When we raised concerns about DWR's lack of documentation regarding its release decisions, the manager of its water operations scheduling section (water operations scheduling manager) asserted that the rationale for DWR's decisions could be drawn from the allocation analysis, the environmental data that the department tracks daily regarding the water supply and conditions in the Delta, and the other documentation discussed above. The data she described are limited to factual information, such as the amount of precipitation that fell and the volume of water exported from the Delta. On review of the data, the water operations scheduling manager was

able to provide some insight into DWR's release decisions in October through December 2020. Nevertheless, the data provided represent possible inputs that DWR used in its decision making on water releases, as opposed to an explanation of how it used those inputs to determine the specific amounts it released. The water operations scheduling manager explained that the rationales for DWR's decisions are not specifically written out in the data, but that she was able to "piece together" what DWR did and why. Overall, the water operations scheduling manager's explanations were consistent with the general idea that water quality issues had required additional releases, but she did not specifically address the magnitude of the releases in question. She stated that experience plays a large role in the decisions that DWR makes and that hindsight about a specific release action is of limited value because DWR does not see the same conditions all the time. We do not dispute that DWR staff should use experience and judgment when making release and other operational decisions. However, documenting the rationale for those decisions is critical for both external accountability and internal oversight of DWR's decision making.

DWR's inadequate documentation of the rationale behind its decisions also prevents it from conclusively demonstrating that it took appropriate and necessary actions to meet water quality and flow standards in the Delta, the second scenario we mention above. In seven of the 14 months we reviewed, DWR and Reclamation did not meet water quality or flow standards.[8] In some of those months, the circumstances demonstrate that DWR took some steps to achieve compliance with the standards, including increasing its releases from Lake Oroville above what it had originally planned or was required. However, the internal records that DWR maintained regarding changes to its planned releases in response to Delta conditions were even less specific than its planning documentation. For example, several records stated only that the increases were in response to "Delta needs" with no information about when DWR discovered the deficiencies in water quality or flow, the specific nature of the deficiencies, the options it considered to address them, or the reasons for the specific volumes of water that it chose to release in response. In the absence of such documentation, DWR cannot adequately demonstrate that it took appropriate steps to remain in compliance with water quality standards. The lack of documentation further hinders DWR's ability to review its own actions to assess their sufficiency.

For some of the months during which DWR did not meet water quality or flow standards, it subsequently provided a better explanation for its actions. It did so twice in the contingency plans we reviewed. However, the more detailed explanations we identified for DWR's decisions existed in letters notifying the State Water Board that it did not meet water quality or flow standards. For example, one such letter explained that higher-than-expected tidal conditions in June and July 2021 had increased salinity in the Delta and that DWR made specific increases to releases as a result. The letter also explained the limitations that DWR faced because of the drought conditions and described efforts DWR had made in place of releasing more water, such as closing the Delta gates to maintain fresher water.

[8] In four of the seven months, DWR asserted that it was unlikely that the water quality issues were a direct result of the projects' operations.

However, these letters varied in the extent of their explanations. Further, the letters exist only because the water quality standards in question were not met; DWR is required to provide written notification to the State Water Board when it does not meet water quality objectives. Therefore, the letters are not a substitute for improved, ongoing documentation of the rationale for DWR's actions. More timely, centralized, and consistent documentation of the options that it considers and the reasons for its choices would better enable DWR to evaluate the effectiveness of those actions and adjust its future decision making if and when necessary.

DWR's limited documentation explaining its water release decisions not only hinders its ability to monitor the effectiveness and appropriateness of those decisions but also impairs its capacity to demonstrate adequate stewardship of the State Water Project. In addition to the challenges it faced in meeting certain of its water quality and flow standards, DWR struggled to meet its objectives in other ways. In 2021 and 2022, DWR's allocations to State Water Project contractors were among the lowest that they had been in 25 years, and the storage levels at Lake Oroville fell significantly below DWR's goals. DWR has attributed these outcomes to the extreme conditions resulting from the drought. We acknowledge both the extreme conditions and the possibility that the releases we observed were necessary to ensure water quality. However, the difficulties DWR faced in meeting State Water Project objectives demonstrate the importance of DWR's consistently documenting clear and detailed information regarding the rationale for the volume of its water releases. Without that documentation, DWR cannot sufficiently demonstrate that it managed those releases to best ensure water quality while also balancing its other objectives, such as maximizing its reservoir storage and providing water to its contractors.

Although DWR's water operations scheduling manager expressed a belief that the department's recordkeeping has been sufficient in the past, she agreed that formally tracking DWR's decisions and rationale for those decisions would assist the department's efforts to review its operations. She further stated that all of DWR's releases were necessary to address water quality or flow issues in the Delta and that DWR did all that was possible to meet water quality and flow standards given the extreme conditions.

Notwithstanding the manager's perspective that DWR's recordkeeping has been sufficient, water releases have a significant effect on a wide range of external stakeholders. This audit was requested in part because of uncertainty about how DWR made its water release decisions, particularly in water year 2021. Our primary critique is therefore the lack of documentary evidence available to understand DWR's decision making in this area. Improved recordkeeping would better position DWR to explain its water release decisions to stakeholders and the general public, and allow it to evaluate its judgment when making specific release decisions.

DWR Needs to Update Key Data for Managing the Lake Oroville Reservoir to Reflect the Possible Effects of Climate Change

As we describe throughout this report, research indicates that climate change has already begun to affect the State's water supply and will continue to do so. Research by DWR and others has identified numerous effects that climate change may have in the State, several of which may directly affect State Water Project operations. For example, DWR has noted that rising sea levels may increase salinity in the Delta, potentially requiring the State Water Project to release more water from its Lake Oroville reservoir to protect water quality. All else remaining constant, such releases would likely result in less water available for other objectives, such as deliveries to water contractors. Indeed, citing the effects of climate change and other factors, DWR has indicated to State Water Project contractors that it will most likely need to reduce water deliveries in future years.

Nonetheless, DWR has not incorporated an assessment of the effects of climate change into its near-term operations. Instead, it has largely relied on historical and possibly outdated data and information when developing its allocation analysis to inform its Lake Oroville reservoir releases and storage. For example, since at least 2005, DWR has based its initial November estimates of the State Water Project's water supply entirely on historical data from 1962 through 2002. It also currently uses those data to estimate the amount of water that will arrive in Lake Oroville during the first three months of the water year. This approach does not account for the extreme conditions that have occurred since 2002, including states of emergency declared because of severe droughts in 2014 and 2021 and flooding in 2017 and 2023. In fact, the estimated water runoff in the Lake Oroville area during the 40-year period from 1962 through 2002 was about 20 percent higher than during the most recent 10 years.

DWR's water operations scheduling manager agreed that its data need to be updated, but she indicated that doing so takes time because of steps that the department must take to verify the quality of the data and because it must coordinate and have concurrence with Reclamation so that they can be consistent in the assumptions they make about hydrology in their planning. However, DWR has been using the same set of data for about 18 years, giving it considerable time to have taken these steps. The water operations scheduling manager stated that DWR is currently coordinating with Reclamation to update the data but was not sure when the update would be complete.

Similar to its estimates of the water supply, DWR has based its Lake Oroville storage target—the amount of water it believes it should retain in storage at the reservoir at the end of each water year in September—on historical water supply data. According to DWR, the storage target represents the amount of water it deems necessary to meet important objectives during subsequent years, such as protecting water quality standards. It is therefore reasonable to expect that DWR would try to account for the possibility of more extreme dry periods when setting its target. Specifically, in 2019 DWR increased its storage target from 1 million acre feet to 1.6 million acre feet, noting that climate change was among its reasons for doing so. However, documentation regarding the increase indicates that DWR established the storage

target using data about historical conditions going up to only 2003, and DWR staff confirmed that the model on which the target was based did not consider the effects of climate change.

In response to our concerns about the limitations of its approach, the deputy director of the State Water Project stated that DWR used the best available tool and data at the time. However, in 2008 DWR advised local agencies that they should plan for droughts that are at least 20 percent more frequent and longer lasting than droughts in the past, a method DWR did not apply when establishing its own storage target. As a result, its approach raises questions about whether its current storage target will enable it to meet its obligations if conditions become drier longer than they have been historically.

In addition to its inconsistently or incompletely documenting its rationale for reservoir release decisions, we found that DWR has not accounted for the possible effects of climate change on certain data that it uses in its reservoir planning. Such documentation issues may affect DWR's planning for reservoir releases and exports from the Delta. Specifically, the allocation analysis that DWR develops each month includes the volume of water that it has determined must flow through the Delta to meet water quality standards. However, when we asked how DWR determined these monthly volumes, its water operations scheduling manager stated that the monthly volumes were in use when she took her position in 2005 and that she believed they might have been based on an older set of water quality standards that are no longer in effect.

DWR's water operations scheduling manager agreed that the department needs to update the storage and water quality data we describe. She said that based on recent extremes in hydrology and potential changes in regulatory requirements, it is likely that DWR will reassess its storage target; however, she also stated that there is not yet a timeline for that reassessment. She also explained that in the past, she considered evaluating the figures DWR uses to determine necessary flow to address water quality standards, but she did not do so because of other priorities. By acting now, DWR may improve its chances of managing and mitigating the projected effects of climate change.

DWR Needs a Regular Process for Evaluating Its Monthly Water Allocation Plans and Water Storage Target

Given the importance of the State Water Project's various objectives, we expected that DWR would have a formal process for periodically evaluating the effectiveness of its reservoir operations planning to ensure the achievement of those objectives. Both state law and federal guidance regarding the management of public programs emphasize the importance of a formal process for monitoring government operations to ensure that an agency is efficiently and effectively achieving its objectives. Further, the guidance indicates that an agency should regularly evaluate the effectiveness of its monitoring process.

However, DWR does not have a formal process for evaluating the effectiveness of its reservoir operations planning. The federal guidance suggests that such reviews should be documented and should include established measures of performance against which an agency can evaluate its success. The reviews should also document corrective actions the agency will take to address any deficiencies in its processes. For example, DWR could assess the frequency with which it meets water quality and Delta outflow standards in a given water year then evaluate its allocation analysis to determine whether changes in that planning could address any deficiencies in its ability to meet the standards. However, DWR lacks policies or procedures requiring any periodic review of this type.

The water operations scheduling manager acknowledged that DWR lacks a formal and regular review process, but she asserted that DWR always assesses and evaluates its current or recent operations with the intention of making improvements. However, the examples of these reviews that she provided did not demonstrate that DWR's informal process is consistent with the formal, regular review and documentation that federal guidance recommends. For instance, she pointed us to informal comments that users of DWR's allocation analyses had added to those planning documents, indicating the desired volume of stored water for a given month. However, the comments do not explain what DWR hoped to achieve through making that adjustment, what deficiency it had observed that led to the adjustment, or what it planned to do, if anything, to achieve the indicated storage level.

A formal process might help DWR identify needed changes to its approach to developing its monthly plans for managing the State Water Project as well as improvements it could make to the data underlying those plans. California's residents, industries, agriculture, and protected wildlife rely on the State Water Project. It is thus critical that DWR take steps to ensure that it manages the project as effectively as possible.

Please refer to the section beginning on page 3 to find the recommendations that we have made as a result of these audit findings.

Other Areas We Reviewed

To address the audit objectives approved by the Joint Legislative Audit Committee (Audit Committee), we reviewed two temporary urgency change petitions (urgency change petitions) that DWR submitted in 2021 and 2022 to the State Water Board, both of which the State Water Board approved with certain conditions. Specifically, we determined whether those urgency change petitions affected water rights holders by requiring them to give up water to which they would otherwise have had access. We also identified the number and status of lawsuits pertaining to the two urgency change petitions.

DWR's Recent Urgency Change Petitions Did Not Require Water Rights Holders to Forfeit Water That They Had a Right to Receive

Urgency change petitions are formal requests to the State Water Board to temporarily change certain conditions of a water rights permit because of an urgent need. Under state law, the State Water Board may approve the urgency change petition by issuing a temporary change order if it makes specific findings established by law. The findings include that the party filing the petition can make the change without injury to any other lawful user of water and without unreasonable effect upon fish, wildlife, or certain other uses of water.

Our review found that DWR's urgency change petitions did not prohibit water rights holders from receiving water that they had the right to receive. DWR and Reclamation filed two joint urgency change petitions in the last two years—one in 2021 and one in 2022. Both were in response to drought conditions. In the petitions, DWR and Reclamation requested modifications to their water rights permits to allow them to reduce the amount of previously stored water that the State Water Project and Central Valley Project were otherwise required to release from their reservoirs upstream of the Delta. The stated purpose of the modifications was to increase water storage for future releases necessary to meet water quality and other standards.

Although state law protects the continuation of a river's natural flow against a change in use by another appropriator, it does not assure the release of stored water, as such water constitutes artificial supply and flow. Consequently, downstream water right holders are not entitled to water previously stored by another party. The temporary change orders found that reductions in DWR's and Reclamation's releases of water that they had previously stored in their reservoirs did not injure downstream water rights holders.

We identified two lawsuits filed against the State Water Board related to its approval of these urgency change petitions. One of the lawsuits includes claims that the State Water Board approved the urgency change petitions without due consideration of the possible impacts on fish and wildlife. The other lawsuit challenges a State Water Board order that, in part, involved a reconsideration of the 2021 urgency change petition. Both lawsuits were ongoing as of March 2023.

We conducted this performance audit in accordance with generally accepted government auditing standards and under the authority vested in the California State Auditor by Government Code section 8543 et seq. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on the audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Respectfully submitted,

GRANT PARKS
California State Auditor

May 25, 2023

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Appendix

Scope and Methodology

The Audit Committee directed the State Auditor to conduct an audit of DWR's management of surface water. The table below lists the objectives that the Audit Committee approved and the methods we used to address them.

Audit Objectives and the Methods Used to Address Them

	AUDIT OBJECTIVE	METHOD
1	Review and evaluate the laws, rules, and regulations significant to the audit objectives.	Reviewed relevant state and federal laws and regulations related to the objectives listed below.
2	Identify the predictive models that DWR and the State Water Board used to prepare for the 2021 drought. To the extent possible, evaluate the accuracy of the current models and whether the departments need to modify these models to perform more accurately going forward to take into consideration California's persistent drought.	• Documented the predictive model that DWR uses to predict the water supply, including whether conditions will be dry or critically dry, and compared it to models used by the agencies identified under Objective 6. • Reviewed water management requirements that are dependent in whole or in part on DWR's water supply forecasts, including in years projected to be dry or critically dry. • Researched and documented best practices for water supply forecasting and reviewed the models available and used by federal and local agencies to develop their water supply forecasts. • Compared DWR's water supply forecasts to the actual observed runoff for water years 2017 through 2022. • Interviewed staff at DWR and reviewed documentation to identify DWR's efforts over roughly the last 10 years to improve its water supply forecasts and adapt them to climate change. • Determined that the State Water Board does not participate in the development of DWR's water supply forecasts.
3	Determine for water year 2021 (October 1, 2020, to September 30, 2021) DWR's projection of how much water would be captured and how much was actually captured to determine whether the State miscalculated the amount of water that would be captured. If so, determine why, by how much, and what was done to ensure miscalculations will not be repeated, including whether responsible parties have been held accountable. Also determine how much water was released from the State's reservoirs and for what reasons.	• Documented the error rates for DWR's forecasts in water year 2021 and, to the extent possible, compared the error rate in its median forecast to the error rates of other agencies identified under Objective 6. • Interviewed DWR staff and reviewed documentation to determine the reasons for DWR's increased error rate in water year 2021. The DWR staff who oversaw the water supply forecasts in water year 2021 still oversaw forecasting at the time of our review. • Interviewed DWR staff and collected documentation to assess DWR's efforts to improve the accuracy of its forecast. • Interviewed staff and collected documentation from a selection of local agencies regarding the effects of DWR's forecasts on their water management operations. • Reviewed State Water Project releases from Lake Oroville to determine the reasons for those releases. We focused our review on Lake Oroville for several reasons, including its size, its importance to the State Water Project's operations, and the relative volume of releases from it compared to other State Water Project reservoirs.

continued on next page . . .

AUDIT OBJECTIVE	METHOD
4 Evaluate whether operational procedures and requirements for reservoirs are appropriate to ensure that sufficient water will be stored. Determine the State's recourse if it determines that too much water has been released or insufficient water is stored.	• Documented best practices for preparing for a drought. We also reviewed and evaluated DWR's relevant planning documents against those best practices. • Reviewed and documented the requirements, including contracts and permits, that govern DWR's storage and release of water from its Lake Oroville reservoir. Again, we focused our review on Lake Oroville because of its size and importance to the State Water Project's operations. • Reviewed and evaluated DWR's Lake Oroville reservoir operational planning process for a selection of months during water years 2021 and 2022, including the methods DWR used to decide how much water it would release, store, and allocate to State Water Project contractors. • Documented steps that the State can take during times of drought, including the State Water Board's curtailment and urgency change petition processes.
5 Identify the real-time feedback mechanisms DWR relies on to determine when it should release water. Specifically, review releases made from reservoirs, including Lake Oroville in July 2021 and February 2022, to determine how state officials decided when and how much water to release.	• Reviewed DWR's process for increasing and decreasing releases from its Lake Oroville reservoir, including the data that it monitors to inform those decisions. • Reviewed releases DWR made from the Lake Oroville reservoir in July 2021, February 2022, and a selection of 12 other months from water years 2021 and 2022. Deficiencies in DWR's records regarding its releases limited its ability to demonstrate the specific reasons for those releases, including releases that were higher than the minimum required amounts in February 2022 and eight other months. July 2021 was among several months we identified in which DWR did not meet water quality standards and had limited documentation of the specific steps it took to attempt to meet those standards.
6 To the extent possible, compare Sierra runoff predictions among the state, federal, and local agencies, such as Turlock, Merced, and CNRFC, to identify the factors that resulted in different predictions and the magnitude of any differences. Assess the extent of collaboration DWR and the State Water Board have conducted with local agencies to improve the State's modeling and data collection.	• Contacted more than 26 local water agencies to determine which agencies developed their own water supply forecasts. The majority we spoke to do not. Of those that did, we selected three: Turlock, Merced, and San Francisco. We documented the water supply forecasting methods that each uses. We documented the same for the CNRFC. • To the extent they were available, compared the forecasts that the local water agencies and CNRFC developed to the actual runoff for water years 2017 through 2021. We compared each agency's error rate in its median forecast to DWR's error rate for the geographic areas where DWR and the agency both developed forecasts. • Compared DWR's, CNRFC's, and the local agencies' models. We determined whether the local agencies and CNRFC considered different or additional data as compared to DWR. • Interviewed staff at DWR and reviewed documentation to determine the steps DWR has taken to improve the accuracy of its forecasts, including any efforts in which it collaborated with other agencies.
7 Review the State's plan to meet its contractual obligations to maintain salinity standards in the Delta and to provide adequate flow to sustain native fish populations. a. Identify how frequently the State has granted urgency change petitions releasing water designated for other purposes. b. Determine how often such petitions have resulted in legal challenges and the outcomes of those legal challenges. c. Determine whether the State requires water rights holders to give up water they would otherwise have had access to if it fails to accurately predict and manage stored water supplies.	• Assessed how DWR accounts for the need to meet Delta water quality and flow standards in its Lake Oroville reservoir operations planning. • For the months we reviewed under Objective 4, documented the frequency with which DWR and Reclamation did not meet water quality or flow standards. We reviewed DWR's records of its actions to attempt to comply with those standards. • Documented the urgency change petitions the State Water Board granted from DWR during water years 2019 through 2022. We determined whether the State Water Board's granting of those urgency change petitions allowed for the release of water that had been designated for other purposes and whether it prevented other water rights holders from receiving water to which they were legally entitled. • Reviewed and documented whether the State Water Board's granting of those urgency change petitions led to lawsuits. We documented the status of those lawsuits.
8 Review and assess any other issues that are significant to the audit.	None identified.

Source: Audit workpapers.

Assessment of Data Reliability

The U.S. Government Accountability Office, whose standards we are statutorily obligated to follow, requires us to assess the sufficiency and appropriateness of the computer-processed information we use to support our findings, conclusions, and recommendations.

In performing this audit, we relied on various electronic data files from DWR, including data on the water supply, reservoir releases, reservoir storage levels, and Delta conditions. To evaluate the data, we interviewed staff knowledgeable about the data and performed testing of the data where appropriate. In all instances, we found the data to be sufficiently reliable for our audit purposes.

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STATE OF CALIFORNIA – CALIFORNIA NATURAL RESOURCES AGENCY **GAVIN NEWSOM**, *Governor*

DEPARTMENT OF WATER RESOURCES
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May 9, 2023

Grant Parks, CPA*
California State Auditor
1621 Capitol Mall, Suite 1200
Sacramento, CA 95814

Dear Auditor Parks,

The California Department of Water Resources acknowledges receipt of the California State Auditor's redacted draft report titled, "Department of Water Resources: Its Forecasts Do Not Adequately Account for Climate Change and Its Reasons for Some Reservoir Releases Are Unclear."

DWR appreciates the California State Auditor staff's effort to fulfill the direction of the Joint Legislative Audit Committee to review DWR's 2021 runoff forecasts and State Water Project reservoir operations in 2020 and 2021. DWR wholeheartedly agrees that managing water resources in an era of climate change requires regular, vigorous examination of standard practices. DWR embraced that ethos starting in 2008, when it created its climate change program. Though managing water supplies for 27 million people through the extraordinary hydrology of the last 10 years is easier in hindsight than in the moment, DWR appreciates the complexity of the examination summarized in the report.

Findings

DWR respectfully disagrees with the audit declaration that DWR has been slow to account for the effects of climate change on key responsibilities related to managing the State's water resources. DWR established a climate change program in 2008 and has released progressive phases of its Climate Action Plan in 2012, 2018, 2019, 2020, and 2022. Each phase of the plan provided cutting-edge analyses and responses to climate change challenges. DWR's leadership in addressing climate change has been recognized by the Climate Registry, at the Climate Leadership Conference, the U.S. Environmental Protection Agency, and the Center for Climate and Energy Solutions. Since 2012, DWR has won 14 awards for climate action including the most prestigious national award available, membership in the Climate Leadership Awards Hall of Fame (2022). ① ②

* California State Auditor's comments begin on page 53.

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While there is always more that DWR can do to adapt to a changed climate, DWR has demonstrated leadership in accounting for the effects of climate change in the field of water resources forecasting and water resources management.

No single, simple model produces a forecast. Forecasting involves a collection of tools that include multiple computer models that inform the forecast assembled by engineers and others working as a team. All the pieces must fit together, and each of the tools must be developed to a certain threshold to be useful in an operational setting.

③ Responding to new climate extremes and conditions outside the bounds of historical experience – like those experienced in water year 2020-21, the focus of the audit -- requires time, because new tools must be developed to characterize conditions and shape forecasts in meaningful ways. Anticipating extreme years like 2020-21, DWR years ago began to develop partnerships with the National Atmospheric and Space Administration (NASA), the U.S. Geological Survey (USGS), the National Oceanic and Atmospheric Administration (NOAA), Scripps Institution of Oceanography, the National Weather Service, California-Nevada River Forecast Center, and other institutions to facilitate the transition of research concepts into relevant forecasting applications. DWR also has increased the use of Aerial Snow Observatory flights that provide data in expanded areas of the Sierra Nevada mountains to help provide more accurate snowpack forecasting. Other areas of completed improvements from the period of June 2021 to February 2022 include:

- Narrowing of hydrologic datasets to the most recent 30-year period (1991-2020) from a 50-year (1966-2015) period in order to better reflect the effect of climate change on snow, precipitation, and runoff.
- Development of new statistical models (Eqn 2022) based on updated, 30-year hydrology using machine learning techniques.
- Improved automation of daily and monthly data collection and calculations.
- Establishment of a new methodology to evaluate and improve 90 percent and 10 percent exceedance forecasts.
- Updating of Water Supply Index methodologies to better account for future precipitation distribution across exceedances, volume prediction, and historical flow regimes.
- Expanded use of machine learning to better classify data based on new climate change models.
- Training for staff on iSnobal to support Aerial Snow Observatory work.

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- Development of iSnobal models for the Tuolumne, Merced, San Joaquin, Kings, and Kaweah watersheds.
- Launching of a pilot program in partnership with Airborne Snow Observatories, Inc. and the National Center for Atmospheric Research to develop coupled atmosphere watershed models in the San Joaquin and Feather River watersheds.

DWR appreciates and will implement the audit recommendation that it establish a formal process to evaluate forecasting models. DWR has been discussing that idea with collaborators, with the intention of incorporating changes to that effect. DWR also agrees that a public-facing web page with annual updates would be helpful for both the department and stakeholders.

DWR respectfully disagrees with the auditor's conclusion that the department does not have a comprehensive, long-term plan for mitigating or responding to the effects of more severe future droughts on the State Water Project. Multiple DWR initiatives mitigate the effects of climate change including severe droughts on the State Water Project. Those initiatives – some complete, others underway – are not encapsulated in a separate document called the "long-term drought plan," but these initiatives nevertheless constitute a comprehensive strategy to mitigate the effects of future droughts. DWR's efforts to respond to future droughts include: ④

- Identifying a set of actions for use during dry periods, described within a Drought Toolkit published by the U.S. Bureau of Reclamation. The Drought Toolkit is developed in coordination with DWR, the California Department of Fish and Wildlife (CDFW), National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service (USFWS), and the State Water Resources Control Board (SWRCB). The Toolkit includes actions that can either mitigate or avoid drought impacts throughout the Central Valley. It was last updated in 2022 and is a living document that will be updated to include additional actions.
- Issuing a "Delivery Capability Report" every two years in which the effects of drought upon the State Water Project's ability to provide water to its customer agencies is quantified. The public water agencies that depend upon State Water Project supplies use this key water resource planning document in their planning and water resource portfolio development. This report has included an estimate of climate change impacts on State Water Project deliveries since 2009. In the most recent 2021 Delivery Capability Report, DWR provided estimates of future conditions that include substantial warming and up to 55 inches of sea level

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rise. For the upcoming 2023 Delivery Capability Report, DWR will continue to deepen the climate analysis by reporting multiple risk-informed scenarios to provide a greater exploration of both droughts and extreme wet weather events.

- Regularly updating DWR's "Climate Action Plan," which was first issued in 2012. DWR recently completed the first part of Phase III of the plan, which assesses the vulnerability of the State Water Project to future, climate change-driven droughts. DWR efforts to address the vulnerabilities captured in the Climate Action Plan include the Delta Conveyance Project, increased storage reserved in Lake Oroville as protection against drought the following year, implementation of Forecast Informed Reservoir Operations for Lake Oroville, and repairs to restore the full capacity of the California Aqueduct to convey water and to prevent future damage to the Aqueduct from subsidence caused by groundwater pumping. DWR is currently developing the second part of the Phase III of the Climate Action Plan, which is an adaptation plan that will include an updated assessment of the effectiveness of the measures already in development and an evaluation of whether additional long-term measures are needed.

The audit report declares that DWR lacks sufficient records explaining some releases from its Lake Oroville Reservoir. DWR contends otherwise. DWR maintains records and detailed data sufficient to demonstrate the rationale for reservoir releases to the State Water Project's most engaged
⑤ stakeholders. Regulators of the State Water Project – including CDFW, NMFS, USFWS, the U.S. Army Corps of Engineers, and SWRCB – have not raised concerns about record keeping, nor have the 29 public water agencies who depend upon State Water Project deliveries. Nonetheless, water management is complex, and DWR acknowledges that its
⑥ documentation may be confusing to non-experts. DWR sees the value in presenting existing records in a more publicly accessible way and will explore reasonable alternatives to make those records accessible.

DWR takes issue with multiple statements in the audit claiming that DWR released more water from Lake Oroville than the minimum required.
⑦ These statements imply that an alternative use exists for the water DWR released to meet multiple water quality and environmental requirements. For example, Figure 9 calls out that "the additional water [released] is about as much as 229,000 households would use in a year," suggesting that this was a viable alternative use for this water. DWR would have had to knowingly and willfully violated environmental and water quality requirements in order to make this water available for municipal water supply.

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The audit report asserts that "… DWR has not incorporated an assessment for the effect of climate change in its near-term operations." This is false. In 2019, DWR increased by 23 percent the target amount of storage saved in Lake Oroville each year to better prepare for drought. This adjustment was made as the direct result of assessing the effect of climate change on near-term operations of the State Water Project. The audit report discounts this adjustment as unrelated to climate change because the size of the adjustment was informed by an analysis using the CalSim 2 model. The audit report does not mention that CalSim 2 is widely used by water resource professionals and was the best available tool at the time. Also missing is a more general acknowledgement that all models have limitations, and yet operational decisions must still be made. These decisions are not made by blindly applying the output of a model, they are made by considering numerous factors, including the limitations of the model and how competing considerations must be balanced. ⑧

As for the audit statement that "DWR needs a regular process for evaluating its Monthly Water Allocation Plans and Water Storage Target," DWR has an established process that includes monthly reviews of previous water supply forecasts and an annual workshop to review operations at the end of the water year. This process includes both internal and external reviews conducted with numerous representatives of the public water agencies that receive water from the State Water Project. ⑨

Recommendations

Many of the audit report recommendations would layer additional processes and procedures on reservoir operations. DWR notes that there is an opportunity cost in terms of human and financial resources to expanding such processes. Neither the regulators nor the customers of the State Water Project have called for DWR to impose the additional, formal processes and reviews the audit recommends. Furthermore, the State Water Project is required to conduct an annual review of its operations to the California Water Commission. The Commission submits that annual review to the California State Legislature. Through its monthly, public meetings, the Water Commission provides a venue for review of State Water Project operations and presentation of information in a manner accessible to non-water experts. ⑩ ⑪

What the California State Auditor seeks to accomplish with its recommendations – ensuring that DWR manages water resources adaptively based on experience – happens in ways apart from the labor- and documentation-intensive processes that would have to be established to fulfill many of the recommendations of the audit. ⑫

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⑫ No amount of paperwork will solve the challenges of climate change. However, a collaborative team of scientists, academic partners, and water managers dedicated to improved forecasting and water management through extreme flood and drought will help keep Californians safe, with secure water supplies, and that is DWR's approach.

Conclusion

DWR would like to share a few points of additional information:

- The shift at DWR is well underway to move from a statistical, record-based forecasting model to water supply forecasts that simulate the physics of interactions among the atmosphere, water as rain or snow, and the land surface – and to do so for individual watersheds, incorporating site-specific features like slope orientation and depth of soil. This shift requires substantial financial and human resources.

- DWR contributed nine of 50 technical papers underpinning the State's Fourth Climate Assessment in 2019 – a demonstration of the department's commitment to climate science. That research included an assessment of the impacts of climate change on the State Water Project.

- DWR continues to work with partner federal agencies (NASA, USGS, NOAA, U.S. Army Corps of Engineers, and U.S. Bureau of Reclamation) to coordinate development of forecasting and water management capabilities for the benefit of all. DWR also is strengthening its partnerships with land stewardship agencies including the U.S. Forest Service, National Park Service, and CAL FIRE for better observations that support better resource management across the watersheds.

- DWR continues to work with academic partners to pivot the best elements of emerging technology and analytical techniques from a research concept to operational implementation. While not every technology or model makes a successful transition, sustained partnerships ensure that the State has the opportunity to keep pace with climate change and its water-related impacts.

The hydrologic conditions in spring 2021 – the focus of much of this audit – were influenced by climate change. DWR reacted quickly to the extreme hydrology and immediately embraced the runoff forecasting error of 2021 as an opportunity to learn, adjust, and improve. We recognize the importance of forward-looking forecasting that embraces extremes. This high-priority work is crucial to water management and governance in

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California. It will be the focus of continual effort and improvement at DWR.

Thank you again for the opportunity to comment on the draft, redacted audit report.

Sincerely,

Karla A. Nemeth

Karla Nemeth
Director, California Department of Water Resources

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Comments

CALIFORNIA STATE AUDITOR'S COMMENTS ON THE RESPONSE FROM THE CALIFORNIA DEPARTMENT OF WATER RESOURCES

To provide clarity and perspective, we are commenting on the response to our audit from DWR. The numbers below correspond to the numbers we have placed in the margin of the response.

DWR's statements are misleading. Our conclusion is not that DWR has not been involved in climate change related efforts, but rather that it has not adequately accounted for the effects of climate change on key aspects of its management of surface water. Despite DWR's acknowledgement in 2008 that a standard of practice that explicitly considers climate change must be adopted along with new forecasting tools, as we describe on pages 16 through 18, it has made only limited progress toward implementing a forecasting model that can better account for the effects of climate change. Prior to its significant forecasting error in water year 2021, DWR made only one formal attempt to adopt a new model that could better account for the changing climate. Similarly, on page 25 we quote text from the Climate Action Plan that DWR references in its response when we state that DWR has reported that climate change poses serious challenges to its operation of the State Water Project. However, as we describe on pages 25 through 29, despite its acknowledgment of those challenges, DWR has not developed a comprehensive plan for mitigating or responding to the effects of more severe future drought caused by climate change. ①

Notwithstanding the awards DWR references, it can do more to demonstrate leadership in addressing climate change. For example, to date DWR has not fully modified its approach to forecasting the available water supply, despite noting in 2018 that climate change might be causing increased errors in its forecasts. Further, DWR's approach for estimating runoff into Lake Oroville as part of its State Water Project planning is based in part on historical data from 1962 through 2002, which was a period when runoff was roughly 20 percent higher than during the last 10 years. ②

We acknowledge that adopting new forecasting methods takes time, but we are concerned with the significant amount of time that has passed between DWR's acknowledgment in 2008 that it needed a new approach to forecasting and the limited progress it has made to date. ③

We disagree with DWR's assertion that the initiatives it references in its response constitute a comprehensive strategy to mitigate the effects of future droughts. As we describe beginning on page 28, we reviewed all of the documentation that DWR provided—including all of the documentation it describes in its response—and concluded that, even collectively, those documents did not address all elements of the best practices for drought planning that we discuss in the report. Specifically, those documents contain high-level discussions of certain impacts of drought, and the Drought Toolkit describes potential actions DWR, Reclamation, and other agencies may take during a drought. However, none of the documents sufficiently assess the potential impacts of more severe future droughts on State Water Project operations or the degree to which such droughts may challenge DWR's ability to meet the project's objectives. ④

They also do not contain clear steps that DWR intends to take to address those challenges. Our conclusion is consistent with the acknowledgment by DWR's manager of water operations on page 28 that she was not aware of specific plans to prepare the State Water Project for droughts that are more severe than past droughts.

⑤ DWR's statement that it maintains records sufficient to demonstrate the rationale for its reservoir releases is inaccurate. We reviewed all of the records that DWR asserted contained this information, and identified significant gaps in those records. As we describe on page 34, when we asked DWR's leadership in the field for an explanation for the specific amounts of water released, DWR was only able to provide limited insight and "piece together" what it did and why. As we conclude on page 35, DWR's limited documentation explaining its reservoir release decisions impairs its ability to externally demonstrate adequate stewardship of the State Water Project and also hinders its own ability to monitor the effectiveness and appropriateness of its release decisions. To illustrate, Figure 9 on page 32 shows that DWR released 153,000 acre feet from Lake Oroville in October 2020, but could not explain how it determined that amount was appropriate versus alternatively higher or lower water releases.

⑥ DWR's suggestion that its reservoir release records are not deficient, but rather too complex for "non-experts" to understand is misleading. Our review of DWR's release decisions was not impeded by the complexity of DWR's data, but rather by the absence of documentation supporting fundamental aspects of those decisions. As we describe on page 34, DWR itself could not provide specific explanations of its rationale for its releases, and instead claimed that hindsight about a specific release has limited value.

⑦ DWR takes issue with factual statements from our report indicating that DWR released more water than the minimum amount required by various standards, criticizing the audit report for incorrectly implying this water could have been used for alternative uses (such as by households). DWR's response misconstrues our report and requires clarification. In order to provide our report's readers with context on the magnitude of DWR's water release decisions, the report equates 153,000 acre feet as enough water to supply 229,000 households for a year. Our point—as we highlight in Figure 9 on page 32—is that DWR could not explain why releasing this specific amount of water was necessary and how the amount released was specifically determined versus potential alternatives. For example, DWR might have instead released 100,000 acre feet or 200,000 acre feet. As we acknowledge on page 33 and elsewhere in the report, DWR's water release decisions may have been necessary to maintain water quality and flow in the Delta; however, the often absent or limited documentation explaining how DWR determined the magnitude of these releases prevented us from evaluating DWR's decisions, as directed by the audit's objectives.

⑧ We acknowledge DWR's 2019 update to its storage target on page 36. We also note on page 37 DWR's confirmation that the model on which the update was based did not consider the effects of climate change. Further, contrary to DWR's assertion, we also acknowledge its perspective that the model it used was the best available tool at the time. However, we conclude that DWR did not apply methods responsive to the assumption of more frequent and longer lasting droughts, as it advised local agencies

to employ, when it established its own target. Finally, as we state on page 37, DWR's manager in the field agreed that the department needs to update its storage target, and that it will likely do so in part based on recent extremes in hydrology.

As we describe on page 38, the records DWR provided for its operational reviews did not demonstrate consistency with the formal, regular review and documentation processes that federal guidance recommends. Federal guidance suggests that such reviews should be documented and should include established measures of performance against which an agency can evaluate its success. The reviews should also document corrective actions the agency will take to address any deficiencies in its processes. The records DWR provided showed that DWR's reviews lacked each of those elements. For instance, to demonstrate DWR's reviews, the water operations scheduling manager pointed us to informal comments that users of DWR's allocation analyses had added to those planning documents, indicating the desired volume of stored water for a given month. However, the comments do not explain what DWR hoped to achieve through making that adjustment, what deficiency it had observed that led to the adjustment, or what it planned to do, if anything, to achieve the indicated storage level. Additionally, as we note on the same page, DWR's water operations scheduling manager confirmed that DWR lacks a formal, regular review process for its reservoir operations planning. (9)

DWR does not specify which of our recommendations it believes would result in unnecessary processes, procedures, and costs. Nonetheless, we stand by the importance of each recommendation in helping DWR ensure improved management of the State's water supply. Our recommendations are informed by best practices in water supply forecasting, drought and emergency planning, and effective management of public programs. (10)

Our recommendations are the result of a comprehensive and detailed audit process that is not broadly comparable to the role played by DWR's external stakeholders. Further, we question DWR's assertion that no such stakeholders or regulators have called for additional processes and reviews. Specifically, in an April 2021 letter to both DWR and Reclamation after the two entities did not meet certain water quality standards during February through May 2021, the State Water Board called for improvements, including to the State Water Project's and Central Valley Project's long-term drought planning and preparedness. (11)

In various places, DWR's response attempts to downplay the audit's recommendations by casting them as bureaucratic, paper-intensive exercises that will not improve its operations. What DWR is not acknowledging in its response is that our recommendations seek to establish an accountability structure where DWR is better positioned to explain its water management decisions to others, particularly with respect to water supply forecasting and water releases from the State's reservoirs. Regardless of whether DWR releases 100,000 or 200,000 acre feet of water, doing so has tangible consequences for households, agriculture, and the environment as the State navigates increased volatility with precipitation and other effects of climate change. Throughout the audit, we held numerous (12)

discussions with DWR staff to understand how they made water release decisions. DWR's water operations scheduling manager summed it up best by explaining that DWR's decisions are not specifically written out, but one can "piece together" what DWR did and why. Given the critical importance of water to the State's various stakeholders, we do not believe DWR is currently well-positioned to promote accountability and transparency for its decision making.